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## **Field Testing and Summary Report for Road 5 (Morris Road) Over Road 3 (Toftoy Throughway) at Redstone Arsenal, AL**

Contractor's Supplemental Report for Project F09-AR16

Brett Commander and Scott Aschermann

August 2016



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# **Field Testing and Summary Report for Road 5 (Morris Road) Over Road 3 (Toftoy Throughway) at Redstone Arsenal, AL**

Contractor's Supplemental Report for Project F09-AR16

Brett Commander and Scott Aschermann

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Final report

Approved for public release; distribution is unlimited.

Prepared for Office of the Secretary of Defense (OUSD(AT&L))  
3090 Defense Pentagon  
Washington, DC 20301-3090

Under Purchase Order BDI0001 from Mandaree Enterprise Corporation under  
Contract W9132T-06-D-0001, Delivery Order 0067, "Lightweight FRP  
Composite Bridge Deck Replacement of a Concrete Deck at Redstone Arsenal,  
Alabama" for Project F09-AR16, "Demonstration and Validation of a  
Lightweight Composite Bridge Deck Technology as an Alternative to Reinforced  
Concrete"

Monitored by Construction Engineering Research Laboratory  
U.S. Army Engineer Research and Development Center  
2902 Newmark Drive  
Champaign, IL 61822

## Abstract

Cyclic loading and weathering of reinforced concrete bridge decks causes corrosion of reinforcement steel, which leads to cracking, potholes, and other problems. Under the Department of Defense Corrosion Prevention and Control Program (Project F09-AR16), a deteriorated concrete bridge at Redstone Arsenal, Alabama, was selected to demonstrate and validate a glass-fiber reinforced polymer (GFRP) composite deck system, which does not use any reinforcement steel. The results of that project were published as ERDC/CERL TR-16-6 (August 2016). Upon completion of the new GFRP composite deck system, Bridge Diagnostics, Inc. (BDI) was contracted to perform load testing to confirm that the bridge meets the structure's original 36-ton (HS-20) load rating and performance criteria for deflection and strain. This report documents the load test methods used by BDI and the results. The test results indicate that the demonstrated GFRP composite deck system met the strength design specifications and passed the deflection criteria.

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**DESTROY THIS REPORT WHEN NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.**

## Foreword

Bridge Diagnostics, Inc. (BDI) was subcontracted by Mandaree Enterprise Corporation (MEC), of Warner Robins, Georgia, to perform load testing on Bridge 18, Morris Road (Road 5) Over Toftoy Throughway (Road 3) at Redstone Arsenal, Huntsville, Alabama. MEC was the prime contractor retained by the Construction Engineering Research Laboratory–Engineer Research and Development Center (ERDC-CERL) to supervise the installation and testing of a glass-fiber reinforced polymer (GFRP) composite deck system to repair the reinforced concrete deck on Bridge 18, which had begun to fracture and spall as a result of reinforcement steel corrosion. The technology was selected for demonstration and validation under Project F09-AR16 of the Department of Defense Corrosion Prevention and Control (CPC) Program. The final technical report on that project was published as ERDC/CERL TR-16-16 (August 2016). The current report, which is incorporated into the technical report by reference, provides complete details on the contractor's execution of the load-testing program.

The primary goal of BDI's live load testing was to determine whether the GFRP composite deck met design specifications for deflection and strain. Their report (reproduced in its entirety here) outlines the testing procedures used, provides a detailed discussion of the data collected, and summarizes the findings.

*Richard G. Lampo  
Project Manager and Materials Engineer  
ERDC-CERL  
Champaign, Illinois*

## Preface

Load testing was conducted by Bridge Diagnostics, Inc. under Purchase Order BDI0001 from Mandaree Enterprise Corporation under Contract W9132T-06-D-0001, Delivery Order 0067, "Lightweight FRP Composite Bridge Deck Replacement of a Concrete Deck at Redstone Arsenal, Alabama" for Project F09-AR16, "Demonstration and Validation of a Lightweight Composite Bridge Deck Technology as an Alternative to Reinforced Concrete." The work was conducted for the Office of the Secretary of Defense (OSD) under the Department of Defense (DoD) Corrosion Control and Prevention Program. The project monitor was Mr. Richard G. Lampo, CEERD-CFM.

The work was monitored by the Engineering and Materials Branch of the Facilities Division (CEERD-CFM), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL. At the time of publication, Ms. Vicki L. Van Blaricum was Chief, CEERD-CFM; Mr. Donald K. Hicks was Chief, CEERD-CF; and Mr. Kurt Kinnevan was the Technical Director for Adaptive and Resilient Installations, CEERD-CZT. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Dr. Ilker Adiguzel.

The Commander of ERDC was COL Bryan S. Green, and the Director was Dr. Jeffery P. Holland.

**FIELD TESTING AND SUMMARY REPORT:  
ROAD 5 (MORRIS RD) OVER ROAD 3 (TOFTOY  
THWY) REDSTONE ARSENAL, AL**



SUBMITTED TO:



*Mandaree Enterprise Corporation*  
812 Park Drive  
Warner Robins, GA 31088  
478.329.8233

SUBMITTED BY:



*BRIDGE DIAGNOSTICS, INC.*  
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April, 2010

## EXECUTIVE SUMMARY

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In January of 2010, Bridge Diagnostics, Inc. (BDI) was contracted by Mandaree Enterprise Corporation (MEC) to perform load testing on Bridge 18, Morris Road (Road 5) over Toftoy Throughway (Road 3) at Redstone Arsenal, Huntsville, Alabama. The primary goal of the live load testing was to obtain and then utilize field measurements to determine whether or not the FRP composite deck met design specifications for deflection and strain. This report outlines the testing procedures, provides a detailed discussion of the data collected, and summarizes the subsequent findings.

The field work phase of this project was completed on March 25<sup>th</sup>, 2010 despite inclement weather including rain and wind. The BDI Wireless Structural Testing System (STS-WiFi) was used for measuring strains at 14 locations and displacements at 9 locations on the deck and superstructure while it was subjected to a moving truck load at several lateral positions. The response data was examined and evaluated in a qualitative manner, and then extrapolated to determine the responses induced by an AASHTO HS-20 design vehicle plus impact (33% per LRFD).

**Please note that the results that follow are based on an estimated load distribution between the test truck's three axles, and may not be entirely accurate. Because individual axle weights could not be obtained (only the truck's gross weight), the results can only provide a reasonable measure of the deck meeting design criteria rather than an absolute conclusion, and must be treated as so.**

The test vehicle was weighed offsite, and was determined to have a gross weight of 78.66 kips. Based on a thorough examination of the field data, it was estimated that the front axle weighed approximately 22 kips, leaving each rear axle at approximately 28.3 kips. In order to extrapolate to the HS-20 design live loading, all front axle responses were multiplied by a factor of 0.364 (8 kips / 22 kips) and all rear axle responses were multiplied by a factor of 1.13 (32 kips / 28.3 kips).

The design specification for strain, provided to BDI by ZellComp, stated that “the strains in the panels under full dead load and design live load shall not exceed twenty (20) percent of the strain at the ultimate capacity of the FRP material” and that “the strains in the panels under dead load alone shall not exceed ten (10) percent of the strains at the ultimate capacity of the FRP material.” Based on the live load test results and subsequent calculations, maximum strains incurred by HS-20 live loading and dead load would be in the range of 800-900  $\mu\epsilon$ , which is significantly smaller than the 3,220  $\mu\epsilon$  limit. Even taking into account possible test truck axle-load distribution discrepancies, it is certain that the FRP deck panels met the **strength** design specifications.

The design specification for deflection stated that “the deck deflection due to live loads plus impact shall be limited to L/500, where L is the distance between the centerline of adjacent girders.” Based on the live load test results and subsequent calculations, deck deflection incurred by HS-20 live loading plus impact would be 0.14 inches, which is approximately 87% of the deflection limit of 0.16 inches. While there is some question as to the actual load test axle weights, it is likely that the estimated weights were within 10 percent. Therefore, the load test results indicated that the deck passed the **deflection** criteria.

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## 1. STRUCTURAL TESTING PROCEDURES

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Bridge 18 at Redstone Arsenal is a bridge deck replacement project located at the intersection of Morris and Toftoy Roads in Huntsville, Alabama. The superstructure consists of four original wide flange beams (W33x118) and a new 7" ZellComp Composite FRP Deck with a 1/2" bituminous wearing surface. The four bridge spans are continuous, and divided into two end spans of 40'-0", an interior span of 64'-4 1/2", and an interior span of 52'-4 1/2". The overall bridge width is 22'-5", with a curb-to-curb roadway width of 20'-0".

The superstructure (beams and deck) was instrumented with 14 strain transducers and 9 Linear Varying Differential Transformer (LVDT) displacement sensors, as shown in Figure 1.1 through Figure 1.9. The intent of the instrumentation was to measure the deck strain and deflection relative to the steel girders. LVDT's were mounted to tri-pods, which in turn were placed on the concrete sloped apron of the abutment. Semi-static load tests were performed with a 3-axle dump truck (speed approximately 5 mph) at three lateral load positions. Strain measurements and truck position were recorded continuously at a sample rate of 40Hz as the test truck was driven across the bridge at crawl speed.

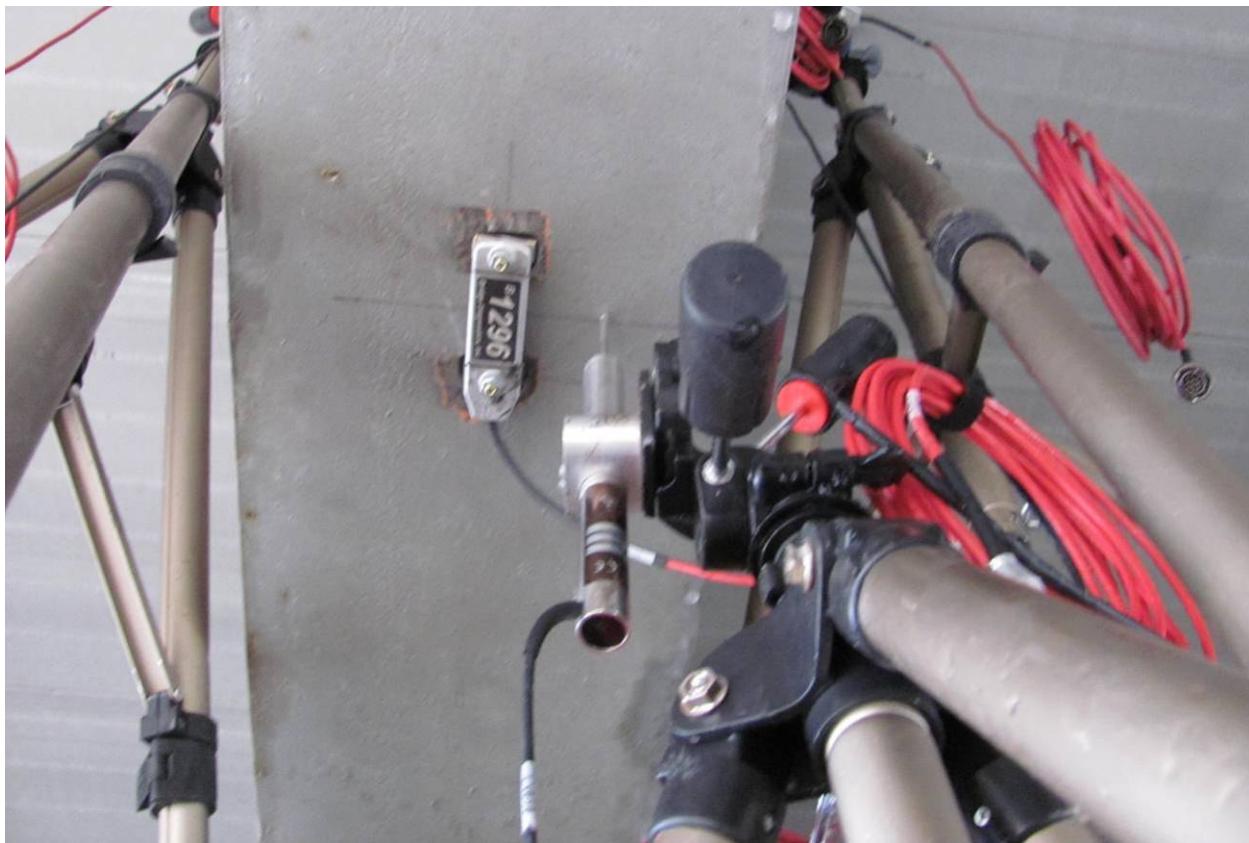
Information specific to this load test can be found in Table 1.1 and the field notes in Appendix B. The test vehicle's gross-weight and wheel rollout distance (required for tracking its position across the structure) are provided in Table 1.2. A "footprint" of the vehicle is also shown in Figure 1.10 for reference. The vehicle weight was obtained off-site and provided to BDI by Angelo Iafrate Construction and MEC.

Please see Appendix C for an outline of the general field testing procedures, and Appendix D for the specifications on the strain transducers and the wireless structural testing system.

**Table 1.1 Structure description & testing notes**

ITEM	DESCRIPTION
STRUCTURE NAME	Redstone Arsenal FRP Bridge
BDI Reference Number	100101AL
TESTING DATE	March 25 <sup>th</sup> , 2010
CLIENT'S STRUCTURE ID #	Bridge 18
LOCATION/ROUTE	Road 5 (Morris) over Road 3 (Toftoy) Redstone Arsenal, Huntsville, Alabama
STRUCTURE TYPE	Steel girders with FRP composite deck
BEAMS/BEAM SPACING	4, 4-span continuous W33x118 / 3 spaces @ 6'-8"
DECK	7" ZellComp Composite FRP, continuous
TOTAL NUMBER OF SPANS	4
SPAN LENGTHS	End Spans: 40'-0" Interior Spans: 64'-4 1/2" and 52'-4 1/2"
SKEW	None

STRUCTURE/ROADWAY WIDTHS	Structure: 22'-5" / Roadway: 20'-0"		
WEARING SURFACE	1/2" bituminous		
OTHER STRUCTURE INFO	N/A		
SPANS TESTED	Southernmost span		
TEST REFERENCE LOCATION (X=0,Y=0) - BOW	Southeast corner, inside edge of curb along face of abutment wall		
TEST VEHICLE DIRECTION	North		
TEST BEGINNING POINT	Front axle at X = -10' from (0,0)		
LATERAL LOAD POSITIONS	Y1 = 3'-2"(P), Y2 = 6'-8"(P), Y3 = 9'-4"(P) Measurements to field "BOW"		
NUMBER/TYPE OF SENSORS	14 – 3" strain gages 9 – LVDT displacement gages		
SAMPLE RATE	40 Hz		
NUMBER OF TEST VEHICLES	1		
STRUCTURE ACCESS TYPE	Ground		
STRUCTURE ACCESS PROVIDED BY	N/A		
TRAFFIC CONTROL PROVIDED BY	N/A		
TOTAL FIELD TESTING TIME	1 Day		
FIELD NOTES	See Appendix B		
ADDITIONAL NDT INFO	N/A		
TEST FILE INFORMATION	FILE NAME	LATERAL POSITION	FIELD COMMENTS
	Red_1.dat	Y1	Truck ~8" east
	Red_2.dat	Y1	Good
	Red_3.dat	Y1	Good
	Red_4.dat	Y2	Truck ~6" east, dynamics
	Red_5.dat	Y2	Truck ~3"-4" east
	Red_6.dat	Y2	Good
	Red_7.dat	Y3	Good
	Red_8.dat	Y3	Truck ~6" west
	Red_9.dat	Y3	Good
COMMENTS	Fairly large, longitudinal crack or seam observed in the wearing surface – see Figure 1.11 and Figure 1.12		



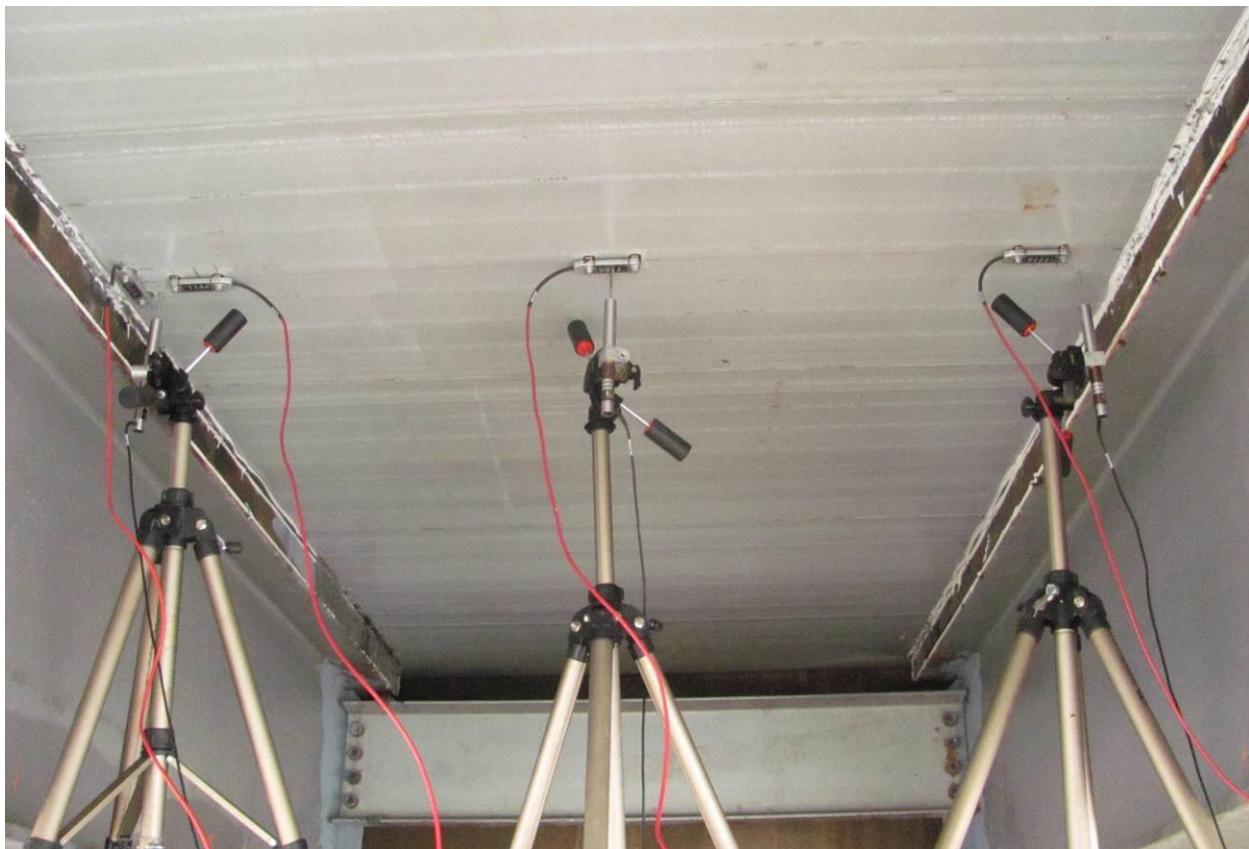
**Figure 1.1 Typical strain gage and LVDT on bottom of beam.**



**Figure 1.2 Typical strain gages and LVDT at top of beam and edge of FRP deck panel.**



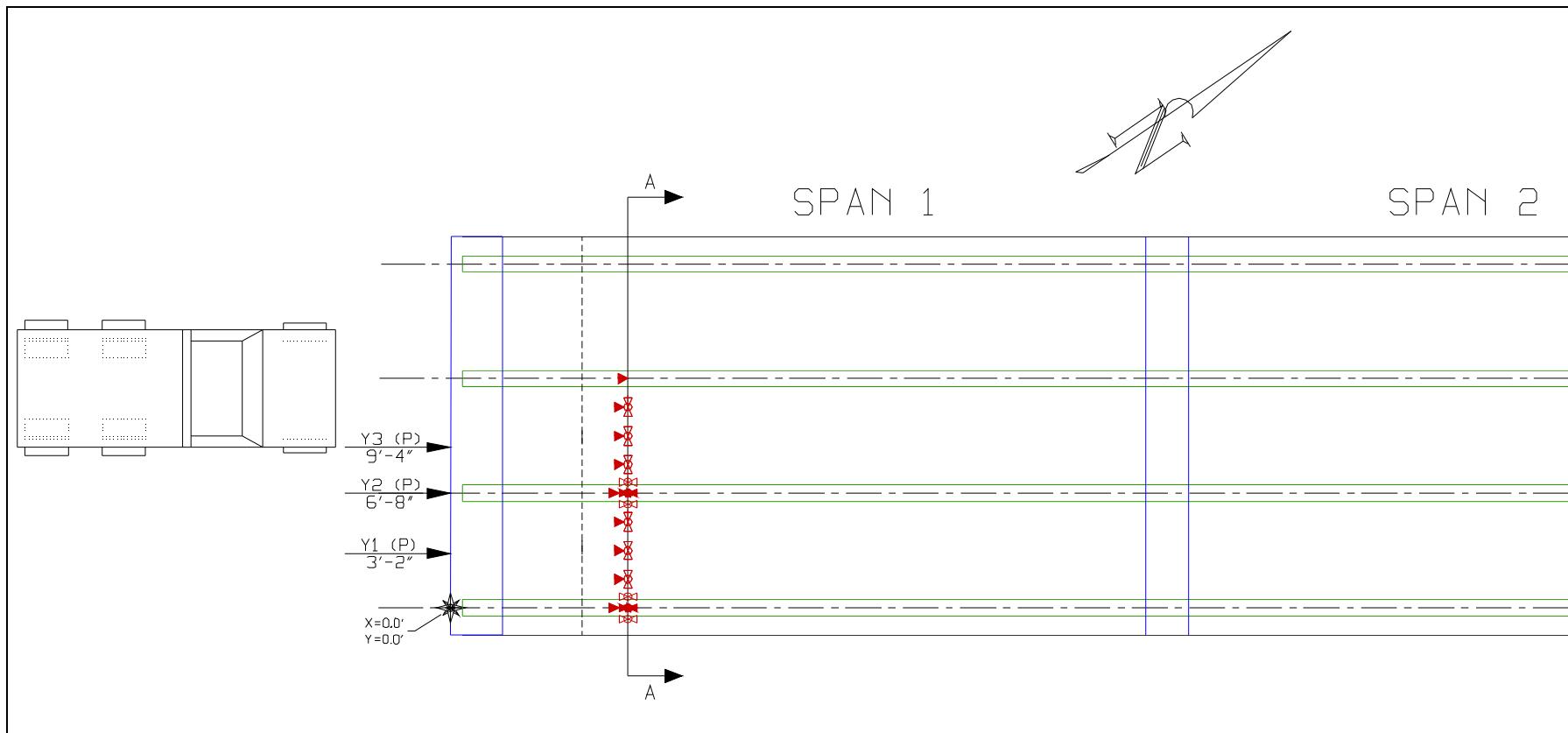
**Figure 1.3 Typical strain gage and LVDT at midspan of FRP deck panel.**



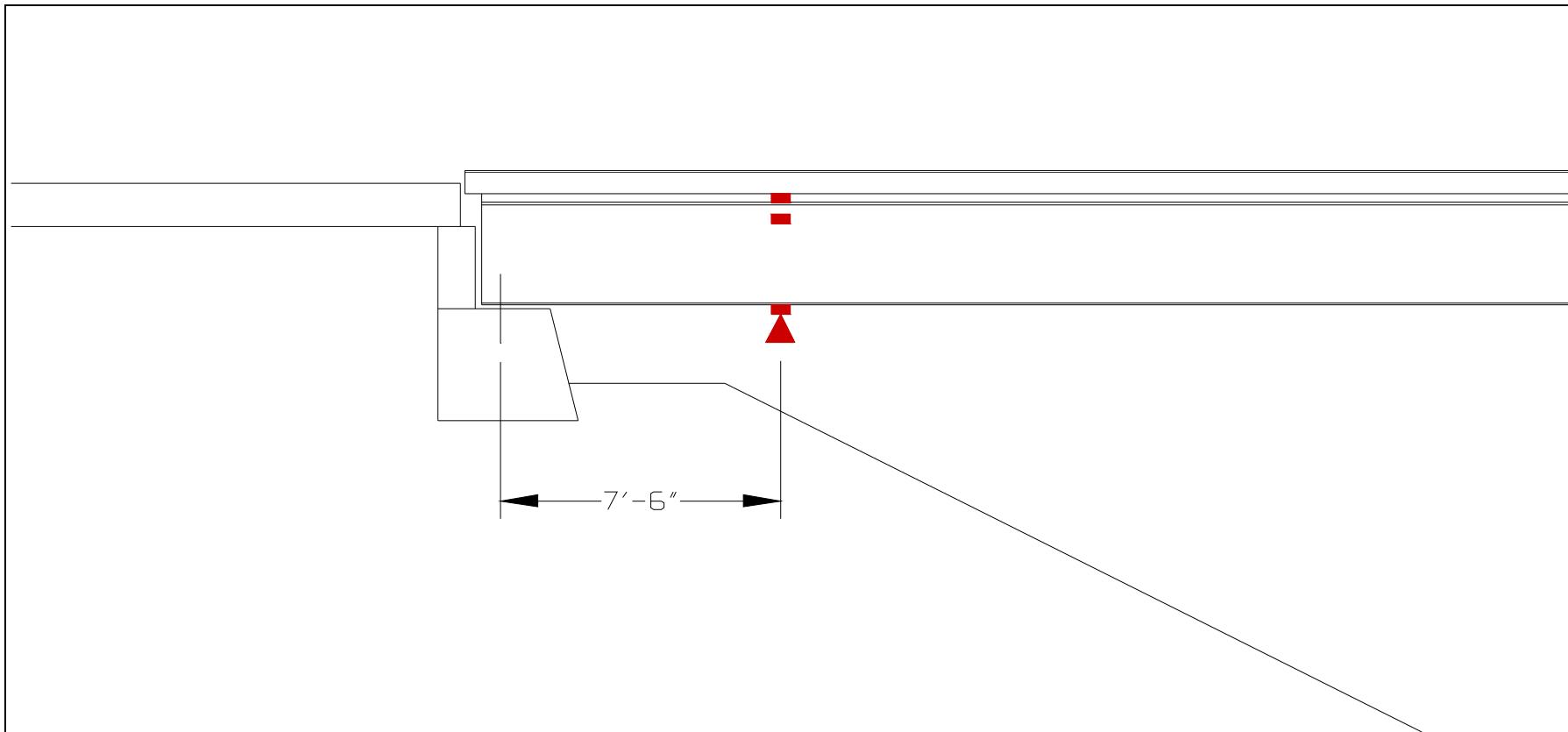
**Figure 1.4 Typical FRP deck instrumentation between beams.**



**Figure 1.5 Overall view of entire instrumentation setup.**



**Figure 1.6 Instrumentation plan with truck positions and gage locations.**



**Figure 1.7 Elevation view with longitudinal gage locations.**

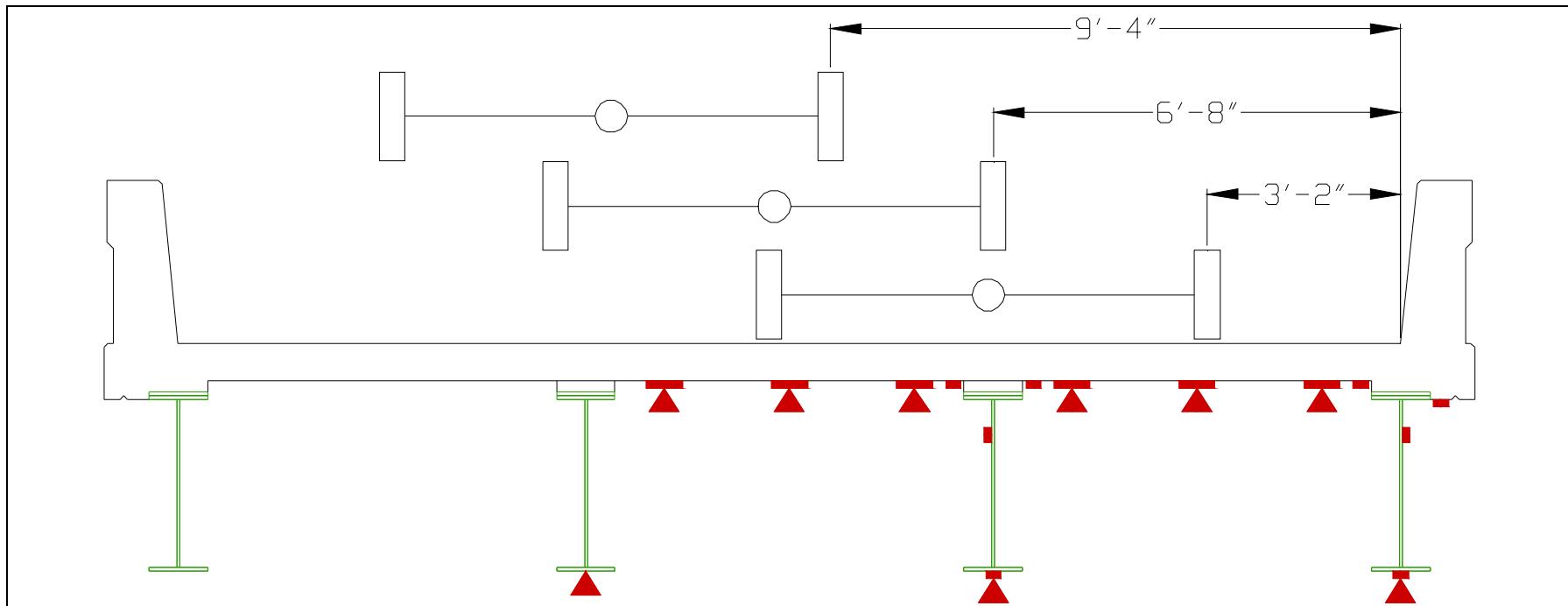


Figure 1.8 Cross-section with gage locations and truck positions.

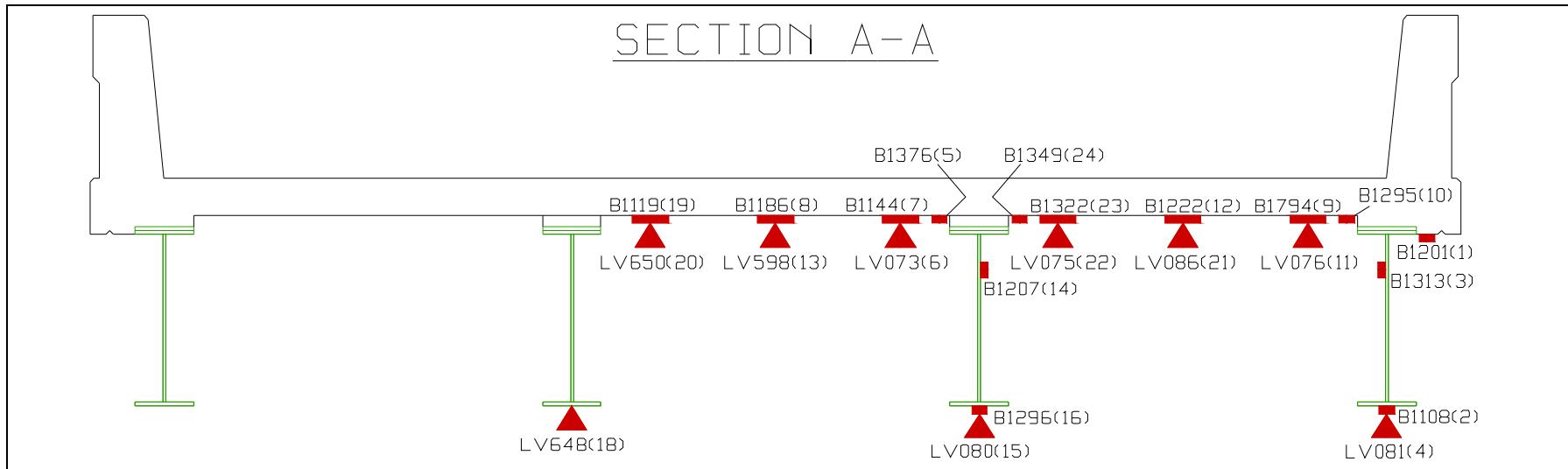
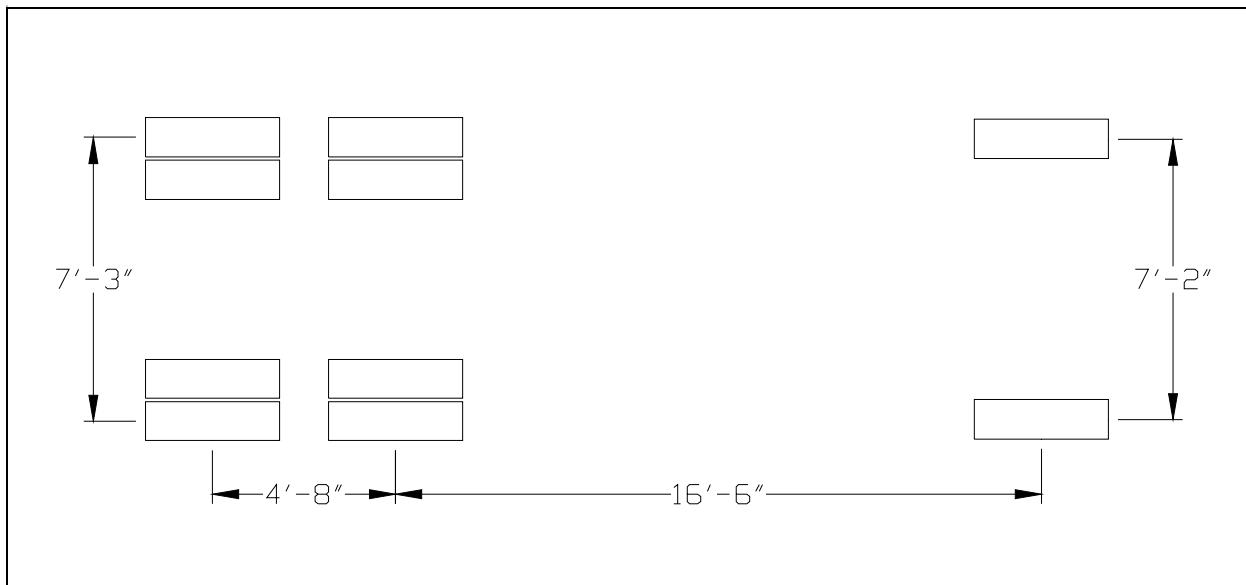


Figure 1.9 Cross-section with gage ID's.

**Table 1.2 Dump truck test vehicle information.**

<b>VEHICLE TYPE</b>	<b>TANDEM REAR AXLE DUMP TRUCK</b>	
GROSS VEHICLE WEIGHT (GVW)	78,660lbs	
WEIGHT/WIDTH - AXLE 1	Unknown	7'-2"
WEIGHT/WIDTH – AXLE 2	Unknown	7'-3"
WEIGHT/WIDTH – AXLE 3	Unknown	7'-3"
SPACING: AXLE 1 - AXLE 2	16'-6"	
SPACING: AXLE 2 – AXLE 3	4'-8"	
WEIGHTS PROVIDED BY	Angelo Iafrate Construction	
AUTOCLICKER POSITION	Manual clicking	
WHEEL ROLLOUT 5 REV	53'-11"	
WHEEL CIRCUMFERENCE	10.78'	
# CRAWL SPEED PASSES	9	
# HIGH SPEED PASSES/SPEED	0	N/A (incomplete roadway)
VEHICLE PROVIDED BY	Angelo Iafrate Construction	



**Figure 1.10 Dump truck vehicle footprint.**



**Figure 1.11 Longitudinal crack or seam observed in wearing surface.**



**Figure 1.12 Longitudinal crack or seam observed in wearing surface.**

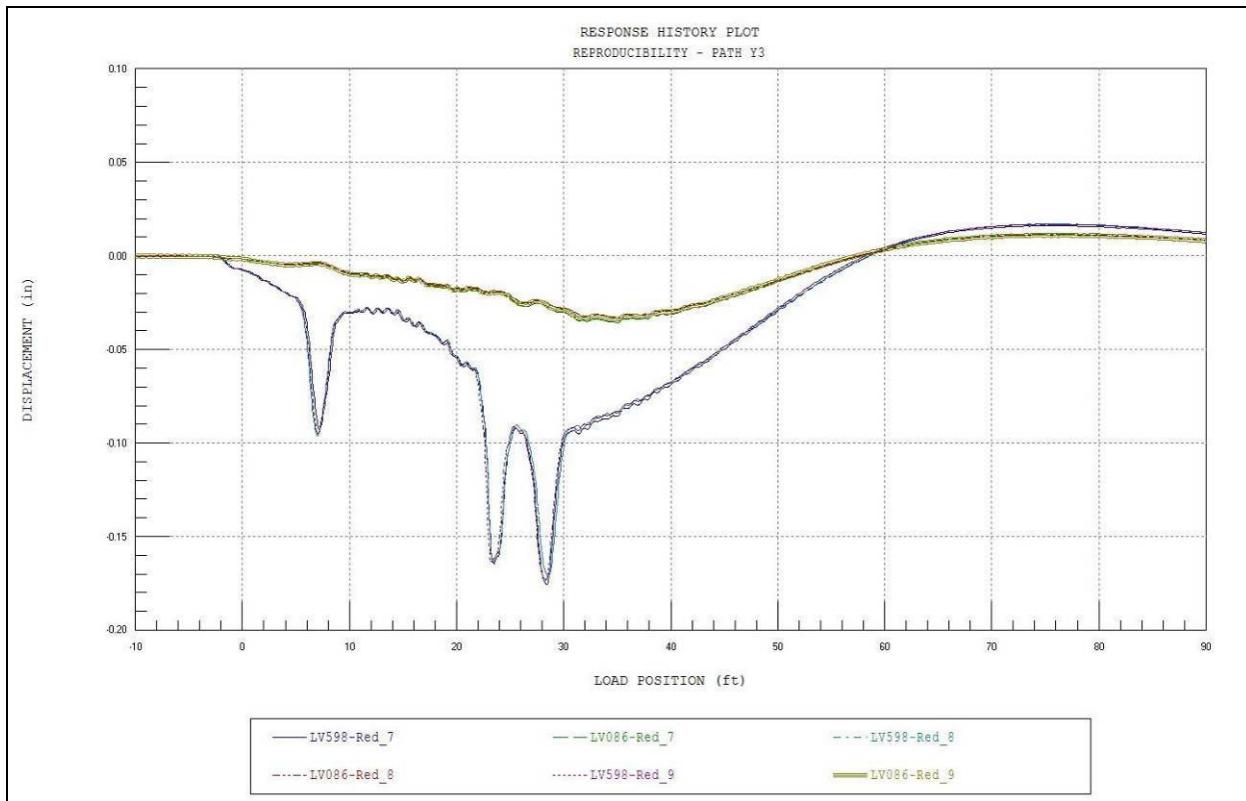
## 2. QUALITATIVE REVIEW OF TEST DATA

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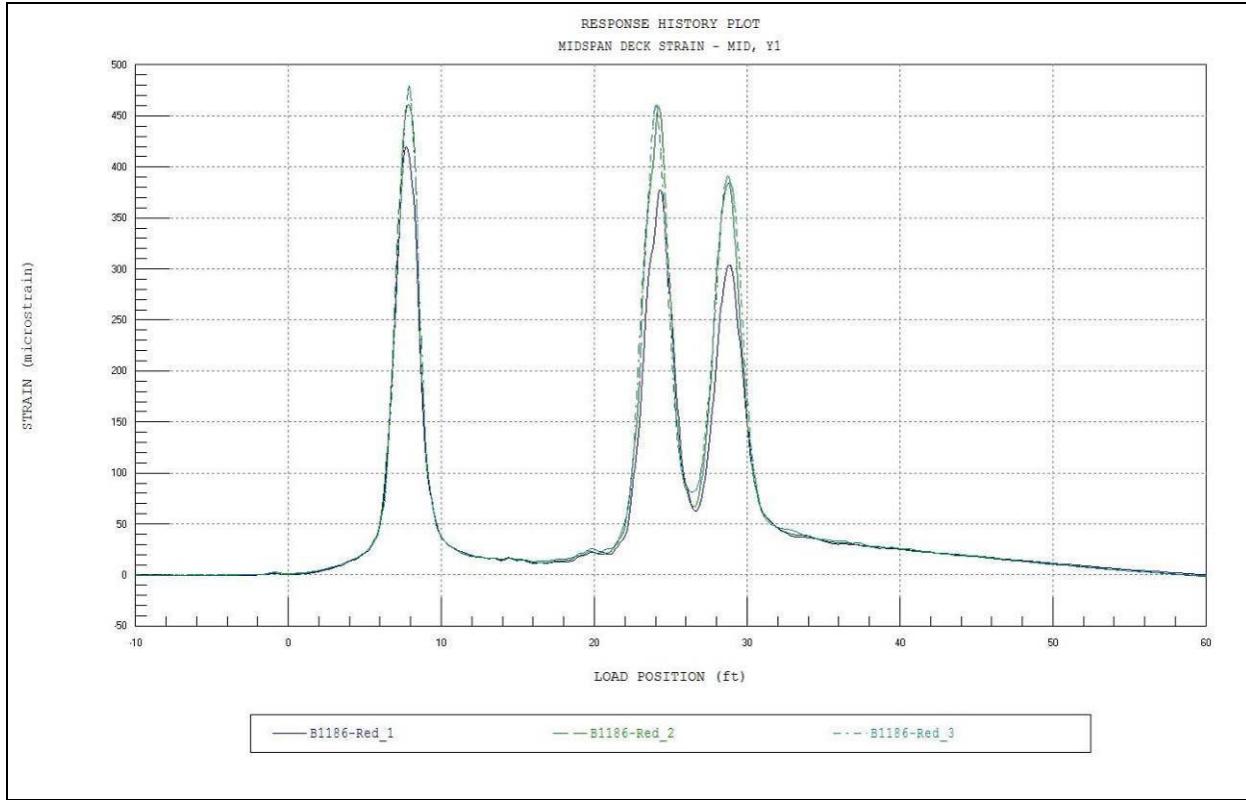
All of the field data was first examined graphically to determine its quality and to provide a *qualitative* assessment of the structure's live-load response. Some of the indicators of data quality included reproducibility between identical truck crossings, elastic behavior (strains returning to zero after truck crossing), symmetry of measurement responses, and any unusual-shaped responses that might indicate nonlinear behavior or possible gage malfunctions.

### ***GENERAL OBSERVATIONS OF TEST RESULTS:***

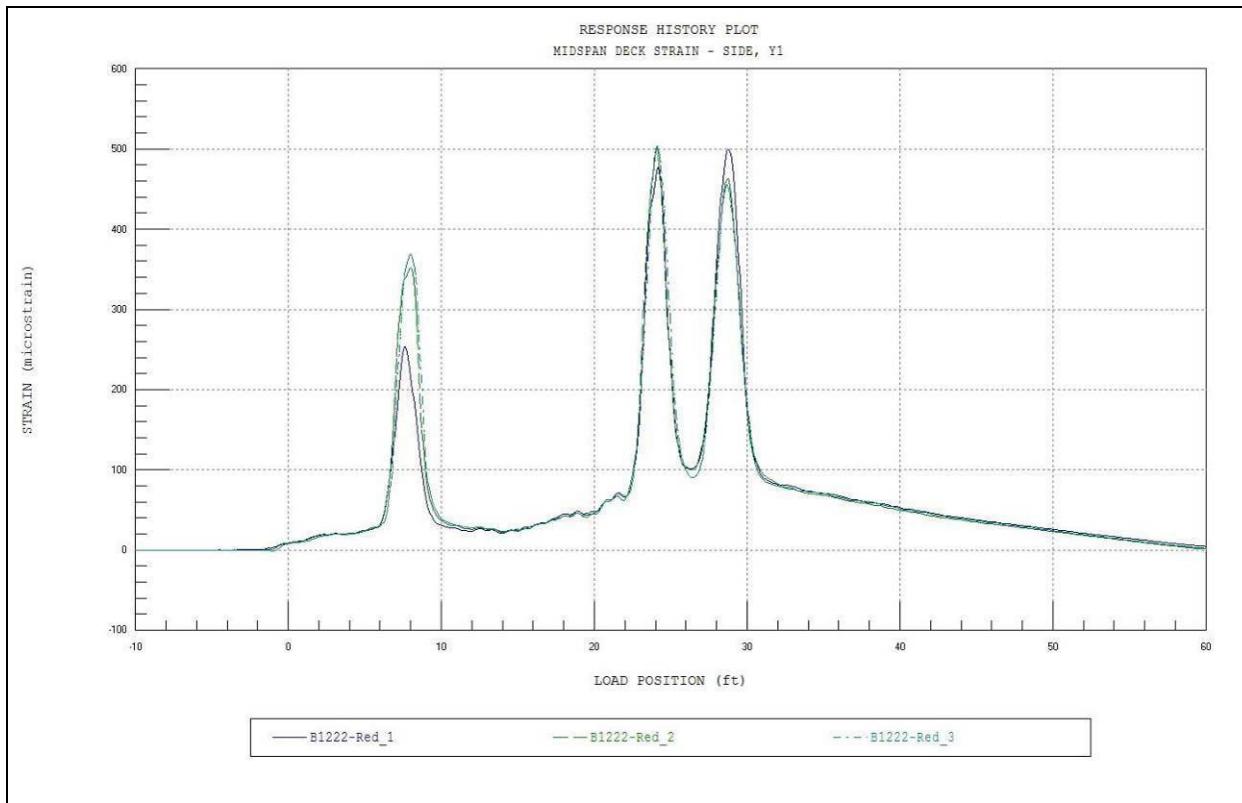
- ***REPRODUCIBILITY AND LINEARITY:*** Responses from identical truck paths were very reproducible as shown in Figure 2.1. In addition, all strains and displacements appeared to be linear with respect to load magnitude (truck position). Note that responses did not return to zero, but this was a result of the beams being continuous over several spans and the test truck not being driven all the way off of the bridge. For all tests, the test truck was stopped near the end of Span 2, which resulted in the strain and displacement response histories displaying negative moment at the end of the tests. Figure 2.1 shows the response histories for midspan deck displacement gages in the middle bay and side bay for three identical truck paths along Path Y3. All of the response histories had a similar degree of reproducibility and linearity indicating that the data collected was of very good quality.
- ***MIDSPAN FRP DECK STRAINS:*** Midspan, flexural deck strains were measured at two locations: in the middle bay directly centered between the two interior beams, and in one side bay directly centered between an interior beam and the corresponding exterior beam. Truck Paths Y1 and Y3 were located so as to generate maximum strains at these specific locations. In general, recorded maximum live load strains were in the range of  $500\text{-}600\mu\epsilon$ , which corresponds to about  $550\text{-}700\mu\epsilon$  for HS-20 design loading (without impact). Figure 2.2 and Figure 2.3 show the flexural deck strains in the two previously described locations for truck Path Y1, while Figure 2.4 shows the deck strain in the middle bay generated by truck Path Y3. Note that deck strain responses are extremely sensitive to variations in lateral truck position, and therefore do not appear quite as reproducible as displacement responses for the same truck paths.
- ***MIDSPAN FRP DECK DEFLECTIONS:*** Midspan deck deflections were measured at the same locations as the midspan deck strains: in the middle bay directly centered between the two interior beams, and in one side bay directly centered between an interior beam and the corresponding exterior beam. However, in order to isolate the relative deck deflection from the total bridge deflection (deck and beams), beam deflections were also measured. By subtracting the average of the two adjacent beam deflections from the total measured deflection at a given midspan deck location, the relative deflection of the deck itself was obtained. Figure 2.5 through Figure 2.8 shows the maximum total midspan deck deflection and respective average beam deflection for each truck path.



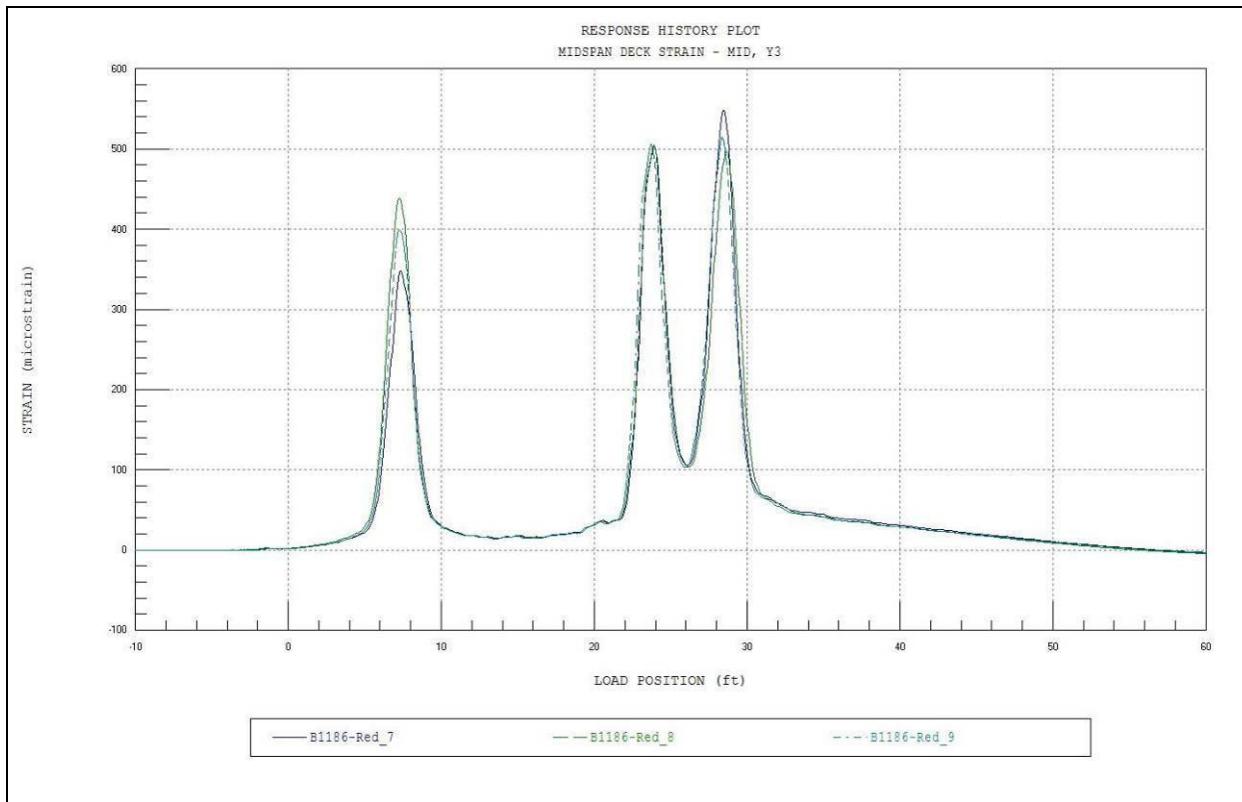
**Figure 2.1 Reproducibility of deck displacement measurements – Path Y3.**



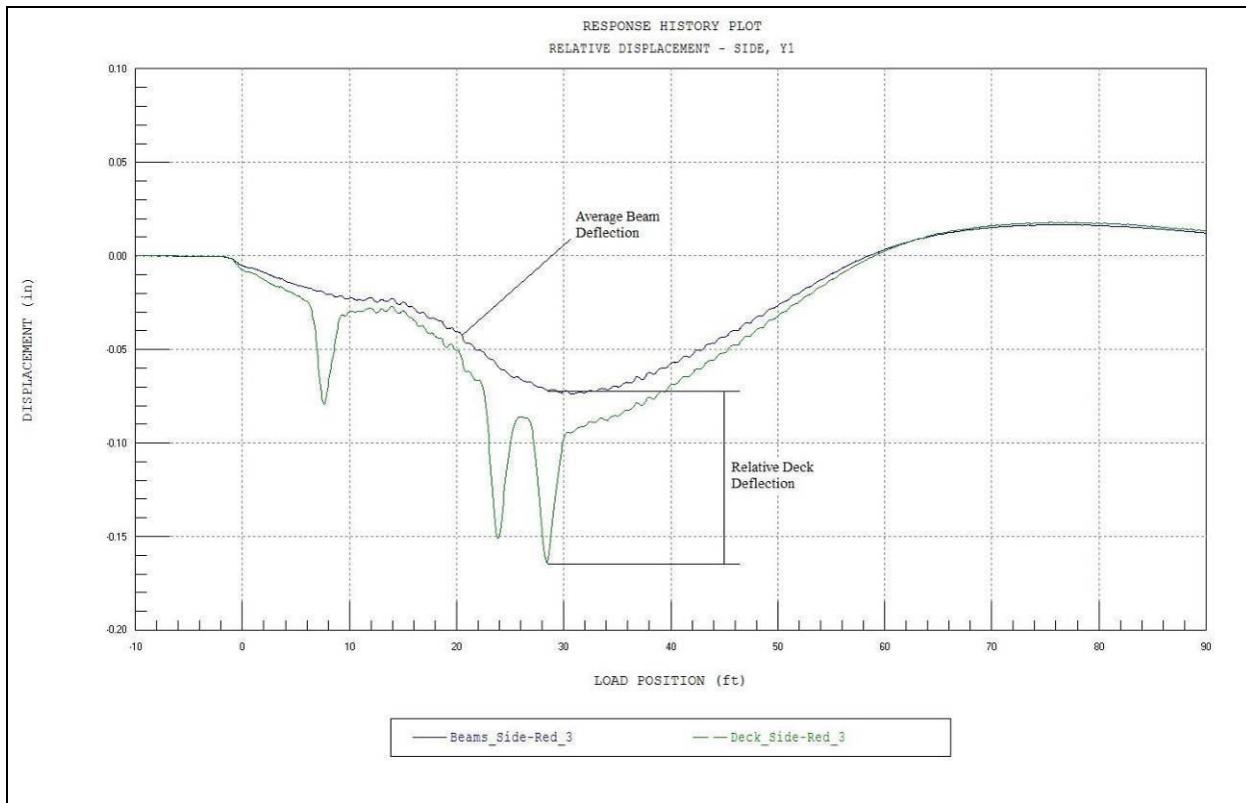
**Figure 2.2 Deck strain measurements at interior bay for 3 truck passes along Path Y1.**



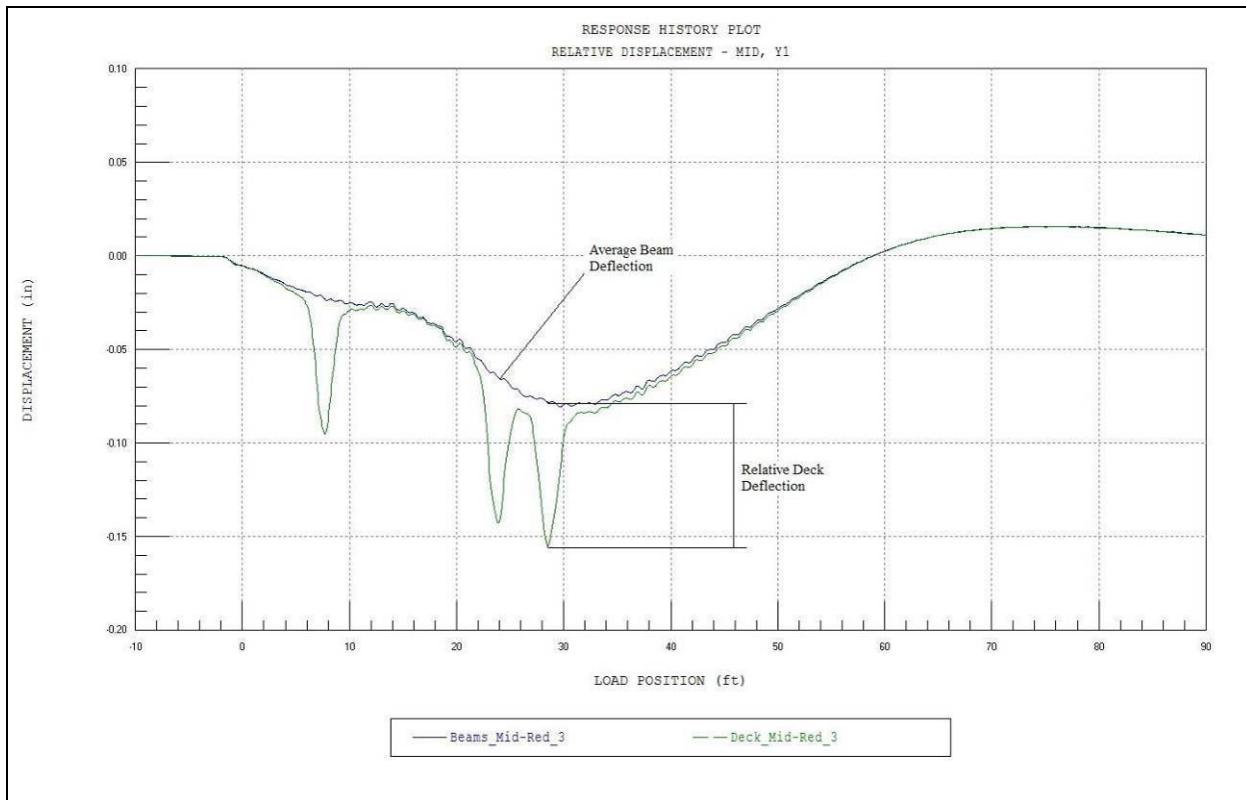
**Figure 2.3 Deck strain measurements at exterior bay for 3 truck passes along Path Y1.**



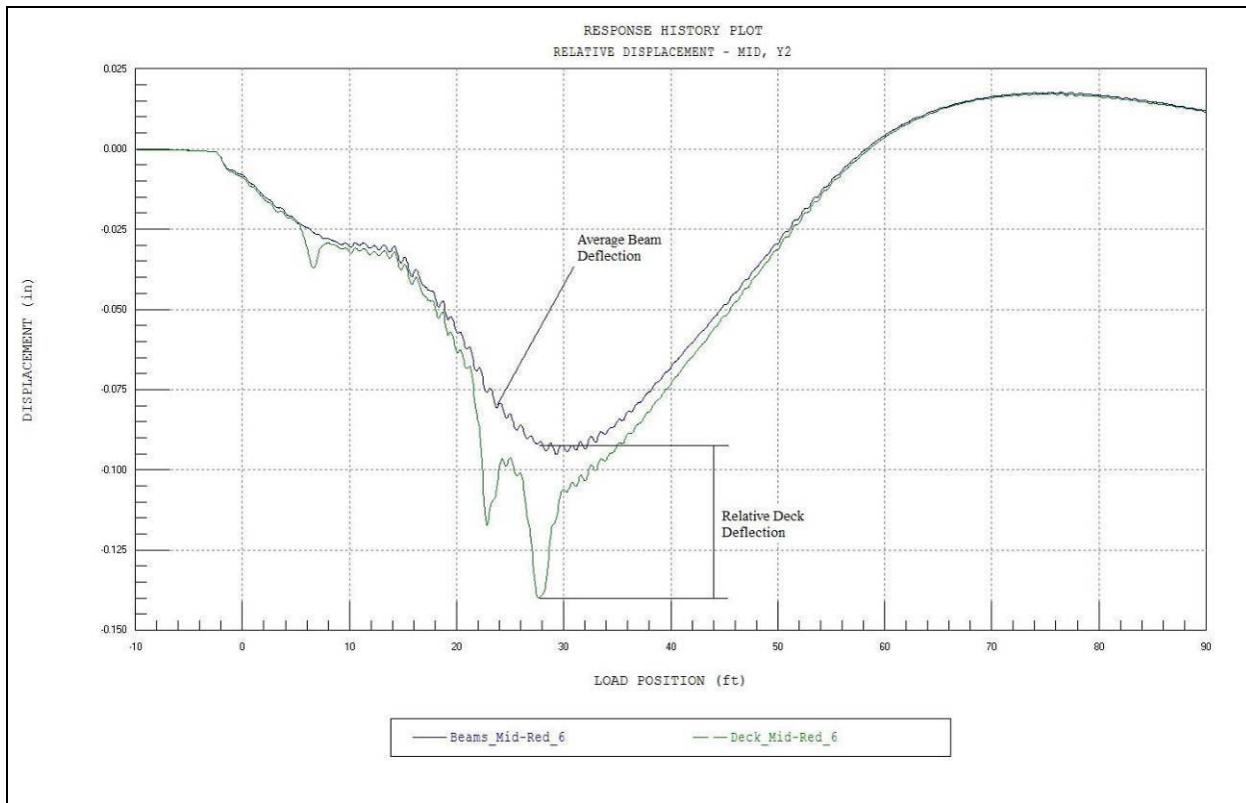
**Figure 2.4 Deck strain measurements at interior bay for 3 truck passes along Path Y3.**



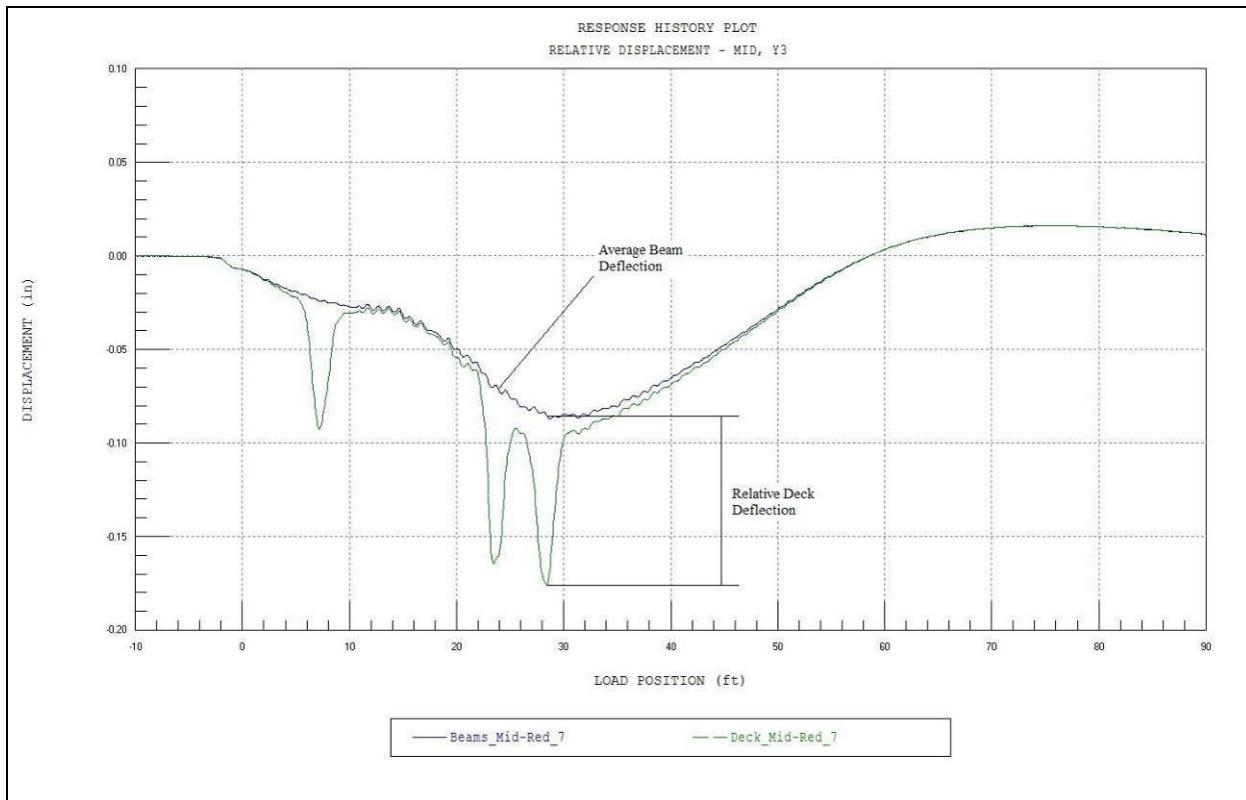
**Figure 2.5 Deck deflection and average beam deflection at outer bay for Truck Path Y1.**



**Figure 2.6 Deck deflection and average beam deflection at inner bay for Truck Path Y1.**



**Figure 2.7 Deck deflection and average beam deflection at inner bay for Truck Path Y2.**



**Figure 2.8 Deck deflection and average beam deflection at inner bay for Truck Path Y3.**

### 3. DATA ANALYSIS AND CALCULATION PROCEDURES

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The goal of load testing this particular structure was to obtain live load strains and deflections that could provide a measure of performance for the FRP deck and verify that it met required design specifications. By quantifying deck strains and deflections under a known loading, strains and deflections under HS-20 design loading could be extrapolated.

It is important to note however, that only a gross weight of the testing vehicle was available and not individual axle weights. This ultimately means that the axle-load distribution had to be estimated based on the collected field data. And because precise weights could not be achieved, these procedures can only provide a reasonable estimate of the deck meeting its design criteria.

#### 1) CALCULATION OF DEFLECTION AND STRAIN LIMITS:

The first step in the process was to calculate the deflection and strain limits as outlined in MEC's Statement of Work (SOW). The design specification for deflection stated that "the deck deflection due to live loads plus impact shall be limited to L/500, where L is the distance between the centerline of adjacent girders." With a center to center girder spacing of 80 inches, the maximum allowable deflection under HS-20 live load plus impact was 0.16 inches.

The design specification for strain stated that "the strains in the panels under full dead load and design live load shall not exceed twenty (20) percent of the strain at the ultimate capacity of the FRP material" and that "the strains in the panels under dead load alone shall not exceed ten (10) percent of the strains at the ultimate capacity of the FRP material." In a Quality Assurance Test Summary Report, written by Creative Pultrusions and provided to BDI by ZellComp, the flexural strength of the FRP material was 44,760 psi with a flexural stiffness modulus of 2.78E+06 psi. Assuming the FRP material remains linear until failure (ultimate strength), the stress-strain relationship shown in Equation 1 yielded an ultimate strain of 16,100 $\mu\epsilon$ . This meant that the dead load strain in the panels could not exceed 1,610 $\mu\epsilon$ , and the combined dead load and live load (plus impact) strains could not exceed 3,220 $\mu\epsilon$ .

$$\sigma = E * \epsilon$$

Equation 1

#### 2) CALCULATION OF ACTUAL DEFLECTION AND STRAIN:

The second step was to review the field data and calculate the maximum deflections and strains under the test truck loading. Deck deflections were calculated by taking the measured total deflection at the midspan of a given deck panel, and subtracting from it the average deflection of the two adjacent steel girders. This process was automated in MS Excel for each data file, and the results of which are provided in the document *Ext\_Data.xls*. Also included in the MS Excel document are the nine data files, which have been extracted in terms of truck position.

Maximum live load strains were taken directly from the field data, and increased by 33% to account for impact and dynamic effects. Dead load strain values were slightly more complicated to calculate, and required a multistep process as outlined below:

1. Calculated an adjusted gross cross-sectional Moment of Inertia,  $I_x$ , based on the ratios of member stiffness values to the bottom plate stiffness value.
2. Calculated a uniform distributed dead load,  $\omega$ , based on the self-weight of the deck panels (17.5 psf) and wearing surface (1/2" x 140pcf).
3. Calculated the middle bay and side bay midspan positive moments based on the assumption of a 3-span continuous beam, Equation 2 and Equation 3.

$$M_{middle} = 0.025\omega L^2$$

**Equation 2**

$$M_{side} = 0.08\omega L^2$$

**Equation 3**

4. Calculated the corresponding dead load stresses based on Equation 4.

$$\sigma = \frac{M \cdot y}{I_x}$$

**Equation 4**

5. Calculated the dead load strains based on Equation 1.

### **3) EXTRAPOLATION TO HS-20 DESIGN LIVE LOAD AND DESIGN VERIFICATION:**

Extrapolating the maximum deflections and strains produced by the test truck to those that would be produced with an HS-20 was as simple as multiplying the calculated values by the ratio of the axle weights of the two trucks. Because the maximum deflections and strains were produced by the rear axles of the test truck, the calculated test truck values were multiplied by a factor of 1.13 (32 kip rear axle weight of an HS-20 divided by 28.3 kip rear axle weight of the test truck). This process produced design-load deflections and strains below the respective specification limits. Table 3.1 shows the maximum deflections and strains produced by the test truck for each of the nine truck passes. Calculations for the extrapolated HS-20 deflections and strain are provided in Table 3.2 along with the corresponding limit checks.

Of moderate concern to BDI was the fact that the individual axles of the test truck were not weighed in the field and therefore had to be estimated based on the test response data. Although the assumed axle distribution was likely close, it could still possibly provide false evidence for the deck meeting (or not meeting) the specified criteria. To help compensate for this possible error, and to provide additional supporting evidence, the deflection calculation was performed backwards in an attempt to “back-out” the axle load distribution that would have caused the deck to fail the deflection criteria. Note that this procedure was not done for the strain criteria because the test strains were substantially lower than the maximum allowable strains and therefore not of concern.

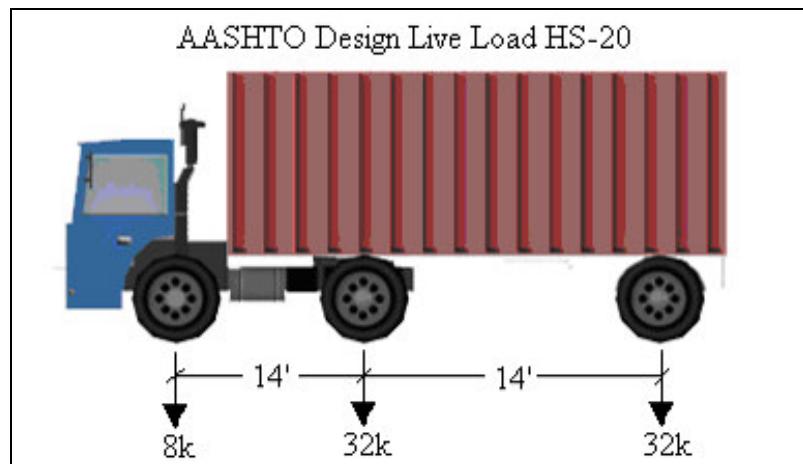
The result of this “backward” calculation showed that in order for the deck to fail the deflection criteria, the test truck’s rear axles would have weighed 25.3 kips and the front axle would have weighed 28.1 kips. This is a very unlikely distribution for a three-axle dump truck, which supports the conclusion that the deck met the design specification for deflection. For reference, Figure 3.1 shows the axle configuration and load distribution of an HS-20 loading vehicle.

**Table 3.1 Maximum FRP deck displacements and strains.**

		Test Y1-1		Test Y1-2		Test Y1-3	
		Max Disp	Max Strain	Max Disp	Max Strain	Max Disp	Max Strain
Middle	0.073	420		0.078	461	0.078	480
	0.085	500		0.091	501	0.092	504
		Test Y2-1		Test Y2-2		Test Y2-3	
Middle	Max Disp	Max Strain	Max Disp	Max Strain	Max Disp	Max Strain	
	0.045	116	0.045	116	0.049	125	
Side	0.010	26	0.011	25	0.009	23	
		Test Y3-1		Test Y3-2		Test Y3-3	
Middle	Max Disp	Max Strain	Max Disp	Max Strain	Max Disp	Max Strain	
	0.095	548	0.095	505	0.095	515	
Side	0.011	6	0.011	4	0.011	5	

**Table 3.2 HS-20 Deflection and strain limit check.**

	Deflection Criteria	Strain Criteria
Maximum Relative Displacement	0.095	548
Plus Impact @ 33%	0.126	729
Extrapolated to HS-20 (x 1.13)	0.143	824
Live-load Limit	0.160	3217
Pass/Fail	Pass	Pass
Rating Factor	1.12	3.91



**Figure 3.1 HS-20 vehicle configuration.**

## **4. CONCLUSIONS AND RECOMMENDATIONS**

---

Load tests indicated that the bridge was performing in a normal manner; all responses were linear-elastic and there were no signs of distress. In addition, all of the response histories had a high degree of reproducibility, indicating that the data collected was of very good quality.

The goal of load testing this particular structure was to obtain live load strains and deflections that could provide a measure of performance for the FRP deck and verify whether it met the required design specifications. By quantifying actual deck strains and deflections under a known loading, theoretical strains and deflections under HS-20 design loading were extrapolated and directly compared to the design limits.

The results of these procedures indicated that the deck met the design criteria for both strain and deflection. Note however, that because individual axles were not weighed in the field and resulting axle-load distributions had to be estimated for calculation purposes, the final results only indicate a high probability of success rather than an absolute certainty of success.

As a whole, the load test was very successful, and the new FRP deck performed as designed.

## A. APPENDIX A – HAND CALCULATIONS (SCANNED)

Bottom Plate:  $E = 2500 \text{ ksi}$

Dims:  $4" \times 0.5"$

Bottom Flange:  $E = 3600 \text{ ksi}$

Dims:  $4" \times 0.17"$

$$\text{Adj} = (4) \left( \frac{36}{25} \right) \times 0.17" = 5.76" \times 0.17"$$

Web:  $E = 2600 \text{ ksi}$

Dims:  $0.5" \times 5.33"$

$$\text{Adj} = (0.5) \left( \frac{26}{25} \right) \times 5.33" = 0.52" \times 5.33"$$

Top Flange:  $E = 3600 \text{ ksi}$

Dims:  $4" \times 0.5"$

$$\text{Adj} = (4) \left( \frac{36}{25} \right) \times 0.5" = 5.76" \times 0.5"$$

Top Plate:  $E = 1500 \text{ ksi}$

Dims:  $4" \times 0.5"$

$$\text{Adj} = (4) \left( \frac{15}{25} \right) \times 0.5" = 4.8" \times 0.5"$$

$$I_x = 104.51 \text{ in}^4$$

$$A = 13.03 \text{ in}^2$$

$\bar{y} = 3.45"$  up from bottom face

## Strain + Deflection Calcs

→ Truck Info:

- Gross Weight = 78,660 lbs
- Front Axle = 22,000 lbs ( $\approx 28\%$ )
- Rear Tandem = 56,660 lbs ( $\approx 72\%$ )

$\left. \begin{array}{l} \\ \\ \end{array} \right\} \text{assumed!!}$

→ Deflection Criteria Check

Test Max = 0.095" w/ a 28.3<sup>k</sup> axle

$$\text{Design check: } 0.095 \left( \frac{32}{28.3} \right) (1.33) = \frac{0.14'' < 0.16''}{\substack{\uparrow \\ \text{Impact}}} \text{ OK}$$

Test Axle Weight to Fail:

$$\begin{aligned} W &= \frac{0.095''}{0.16''} (32)(1.33) = 25.3^k \text{ rear axle} \\ &= 50.5^k \text{ tandem } \left. \begin{array}{l} \\ \end{array} \right\} * \text{NOTE*} \\ &= 28.1^k \text{ front } \left. \begin{array}{l} \\ \end{array} \right\} \text{OK} \end{aligned}$$

→ Strain Criteria Check

$$\text{DL Deck} = 17.5 \text{ psf}$$

$$\text{DL wearing surface} = (140 \text{pcf}) \left( \frac{\frac{1}{2}''}{12} \right) = 5.83 \text{ psf}$$

$$W_{\text{DL}} = \left( \frac{8''}{12''} \right) (17.5 + 5.83) = 15.56 \text{ plf}$$

$$M_{\text{middle}_{\text{DL}}} = 0.025 W L^2 = 0.025 (15.56) (6.67)^2 = 17.3 \text{ lb-ft}$$

$$M_{\text{side}_{\text{DL}}} = 0.08 W L^2 = 17.3 \left( \frac{0.08}{0.025} \right) = 55.3 \text{ lb-ft}$$

$$\sigma_{\text{middle DL}} = \frac{My}{I} = \frac{(17.3 \text{ lb-ft})(12)(3.45 \text{ in})}{104.51 \text{ in}^4} = 6.85 \text{ psi}$$

$$\epsilon_{\text{middle DL}} = \frac{\sigma}{E} = \frac{6.85 \text{ psi}}{2.5 \cdot 10^6 \text{ psi}} \times 10^6 = 2.7 \mu\epsilon$$

$$\sigma_{\text{side DL}} = \frac{My}{I} = \frac{(55.3)(12)(3.45)}{104.51} = 21.9 \text{ psi}$$

$$\epsilon_{\text{side DL}} = \frac{\sigma}{E} = \frac{21.9}{2.5} = 8.8 \mu\epsilon$$

$$\begin{aligned} \Rightarrow \epsilon_{\text{total max}} &= \epsilon_{\text{LL HS20}} + \epsilon_{\text{DL}} \\ &= 5458 \left( \frac{32}{28.3} \right) (1.33) + 2.7 \\ &= 827 \mu\epsilon \ll 3220 \mu\epsilon \text{ OK} \end{aligned}$$

Pass / Fail Criteria

→ Deflection:  $\frac{1}{500}$

$$6'8'' = 80''$$

$$\frac{1}{500} = \frac{80}{500} = \underline{0.16''}$$

→ Strain:  $\epsilon_{DL} + \epsilon_{LL} \leq 0.20(\epsilon_{uHimate})$ ,  $\epsilon_{DL} \leq 0.10(\epsilon_{uHimate})$

$$F_u = 44,760 \text{ psi} \quad E = 2.76 \cdot 10^6 \text{ psi}$$

$$\sigma = E\epsilon \rightarrow \epsilon = \frac{\sigma}{E} = \frac{44.76}{2760} \times 10^6 = 16,100 \mu\epsilon$$

• Dead Load

$$\epsilon_{DL} \leq 0.10(16,100) = \underline{1,610 \mu\epsilon}$$

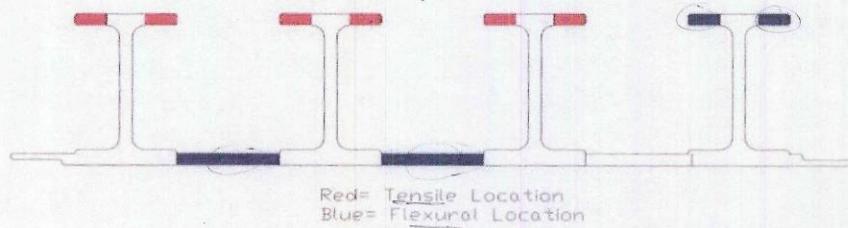
• Dead Load + Live Load

$$\epsilon_{DL} + \epsilon_{LL} \leq 0.20(16,100) = \underline{3,220 \mu\epsilon}$$

**Creative Pultrusions**  
**Quality Assurance**  
**Test Summary Report**

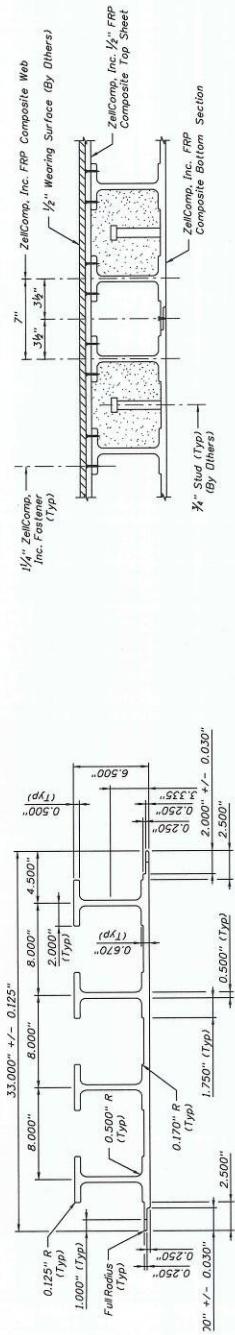
Part Id:	CP216.102	Date Tested:	December 21, 2009			
Description:	7" Bridge Deck	Date Produced:	December 18, 2009			
Production Order:						
<b>Mechanical Properties</b>						
	ASTM Test	Results		Minimum Required		
	Average	Std. Dev.	Units			
Tensile Strength Lengthwise	D638	45,304	2,685	psi		
Tensile Modulus Lengthwise	D638	4.32E+06	2.37E+05	psi		
Flexural Strength Lengthwise	D790	44,760	3,113	psi		
Flexural Modulus Lengthwise	D790	2.78E+06	2.31E+05	psi		

See Drawing below for sample location.

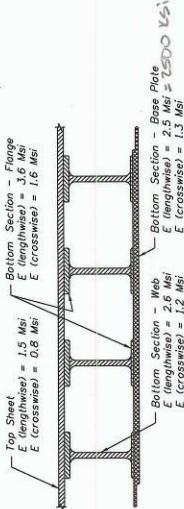
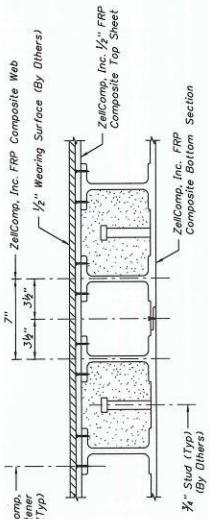


Tested By: D. Crawford  
 Quality Assurance Specialist

Approved By: D. Allison  
 Quality Assurance Supervisor



**TYPICAL BOTTOM SECTION TRANSVERSE SPLICE**



**NOTES:**

1. E (lengthwise) = modulus in machine direction (parallel to fiber axis) and cross-section of laminate.
2. E (crosswise) = modulus in transverse direction (perpendicular to fiber axis).
3. Modulus indicated as representative values, which differently constructed areas of the deck.
4. Space Zellcomp Inc. fasteners at 12" Max. unless noted otherwise.
5. Provide splice plates on each face of each bottom section web.
6. For stud spacing see XX. Place studs in outer two deck section bays as shown.



HARDIEST & HANOVER, LLP MANUFACTURER/PROJECT OWNER		DATE: 05/26/2009		REVISION: 0		REVISION: 0	
Engineer	Timothy J. Niles, P.E. # 26949	Project Manager		Designer		Reviewer	
Shane M. H. Hart	HARDIEST & HANOVER, LLP SUITE 154 Birmingham, AL 35203	Project Manager		Designer		Reviewer	
Checked by	T. N. G. I. N. F. E. R. I. N. G.	Project Manager		Designer		Reviewer	
RELOC. NO.		PROJECT ID		OWNER NAME		OWNER ADDRESS	
DIRECTOR	5	MA/50N		REDSTONE ARSENAL		REDSTONE ARSENAL	
DIRECTOR				DATE: 05/26/2009	TIME: 09:00 AM	DATE: 05/26/2009	TIME: 09:00 AM
						REF. NO.: 06	REF. NO.: 06
						SET. NO.: 511	SET. NO.: 511

## B. APPENDIX B – FIELD NOTES (SCANNED)

**FIELD NOTES & TESTING CHECKLIST**  
(TYPICAL BEAM-SLAB BRIDGES)

PROJECT NAME OR #: Redstone

FIELD NOTE TAKER: Dan DATE: 3/25/10

STRUCTURE NAME OR ID: \_\_\_\_\_

3 CAD DRAWINGS: 1-Gage ID, 1-Gage Dimensions, 1-General Dimensions.

**MEASUREMENTS AND GAGE INSTALLATION PROCEDURES (BELOW)**

SPAN LENGTH(S): \_\_\_\_\_

SKEW: YES NO ANGLE: \_\_\_\_\_

BEAM SIZE: \_\_\_\_\_ BEAM SPACING: 6'-8"

DIAPHRAGM SPACING: \_\_\_\_\_ SIZE: \_\_\_\_\_

BENT INFO: SIZE: \_\_\_\_\_ # OF PILES: \_\_\_\_\_ PILE SPACING: \_\_\_\_\_

GAGE INSTALLATION: 1. Measure gage location & write it on the beam.  
2. Install gage and take picture(s) w/ a reference point.  
3. Write gage ID and dimensions on CAD notes.  
4. Repeat for every gage location!!!  
5. Take multiple pics from different angles.

SUPPORT CONDITIONS: \_\_\_\_\_

ABUTMENT DETAILS – ELEVATION VIEW  – PLAN VIEW  REFERENCE BOW!!

DECK THICKNESS: \_\_\_\_\_ COMPOSITE: YES NO

GENERAL OBSERVATIONS: \_\_\_\_\_

1

**Figure B.1 Scanned Notes- Page 1.**

## MEASUREMENTS AND TESTING PROCEDURES (ABOVE)

BEGINNING OF WORLD (BOW)  
(X=0, Y=0, location)

VERIFY NORTH ON PLANS:  YES NO

Front Face of abut wall, inside edge of barrier → SE corner  
BOW PHOTOS:  ROAD MARKINGS PHOTOS:

ROADWAY WIDTH (CURB-TO-CURB): 19'-10" SYMMETRIC:  YES NO

STRUCTURE WIDTH (Out-to-Out): 22'-8" out-to-out of barriers

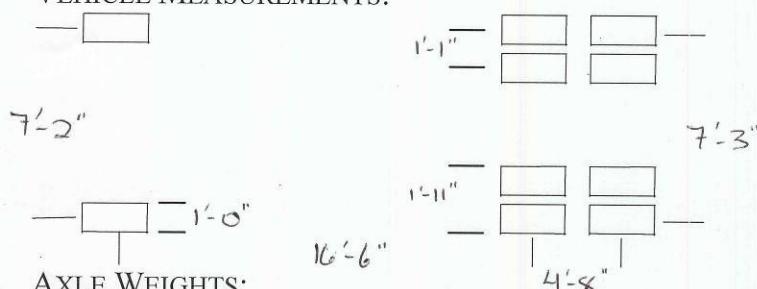
WEARING SURFACE: Gravel compound THICKNESS:

STARTING TEST POSITION: -10' (no 1/2 rev) DIRECTION:  $\approx$  North

VEHICLE ROLL OUT (5 Revs!): 53'-11" A/C LOCATION: None  
\*\*\*\*\*MAKE SURE YOU PUT THE A/C ON THE SAME WHEEL AS WAS USED TO MEASURE THE ROLL OUT\*\*\*\*\*

Manual  
click

VEHICLE MEASUREMENTS:



FRONT: REAR: GROSS: 78,660

VEHICLE PROVIDED BY: Angelo Infratec Construction

TRAFFIC CONTROL PROVIDED BY: None

ACCESS PROVIDED BY: None

2

Figure B.2 Scanned Notes- Page 2.

LATERAL TESTING POSITIONS: (REFERENCED FROM BOW)

Y1: 3'-2" (P) Y2: 6'-8" (P)

Y3: 9'-10" (P)\* Y4:

Y5: Y6:

LATERAL POSITIONS CHECKED BY: Scott

TESTING OPERATIONS (WINSTS)

VERIFY GAGE ID & # OF CHANNELS WITH WINSTS:

RUN WINSTS TO VERIFY RESPONSES:

WEATHER CONDITIONS &

AMBIENT TEMPERATURE: Breezy, rainy, + cold!  $\approx 50^{\circ}$  F

RUNNING THE FIELD TESTS

STS OPERATOR: Dan

TRUCK OPERATOR: Scott

CONTROLLED SEMI-STATIC TESTS

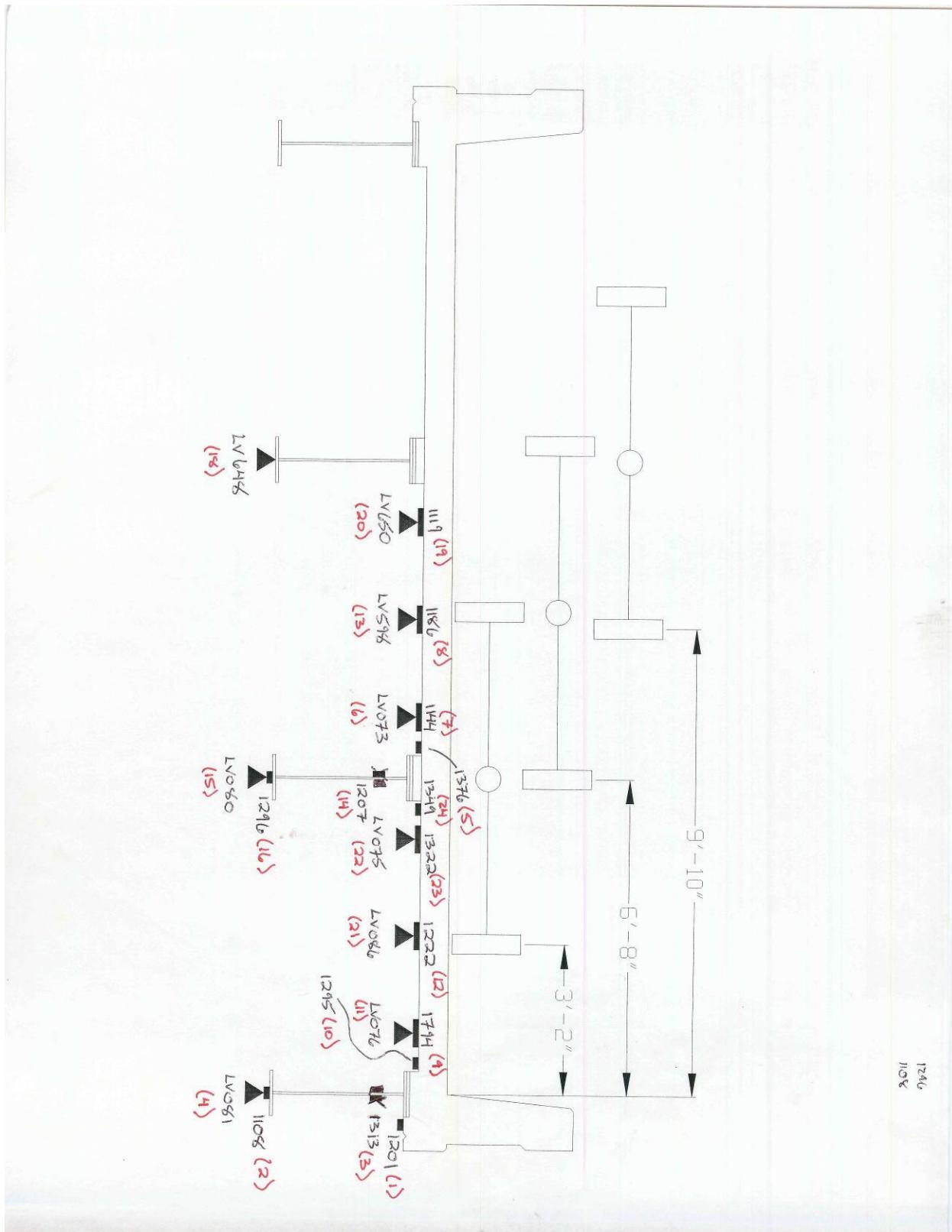
SAMPLE RATE: 40 Hz

GAIN: 32

FILE NAME	LATERAL POSITION	COMMENTS
Red-1.dat	Y1	$\approx 8"$ toward barrier, forgot to stop test! (East) Got truck on the way back
-2.dat	Y1	Good, truck right on line
-3.dat	Y1	Good
-4.dat	Y2	Rocking when came onto bridge, tire width toward barrier (East)
-5	Y2	Good, $\approx 3\text{'-}4"$ toward barrier (East)
-6	Y2	Good, right on
-7	Y3	Good, see note below
-8	Y3	Good, about 6" west, so 9'-110"
-9	Y3	Good, <del>9'-10"</del> 9'-110"

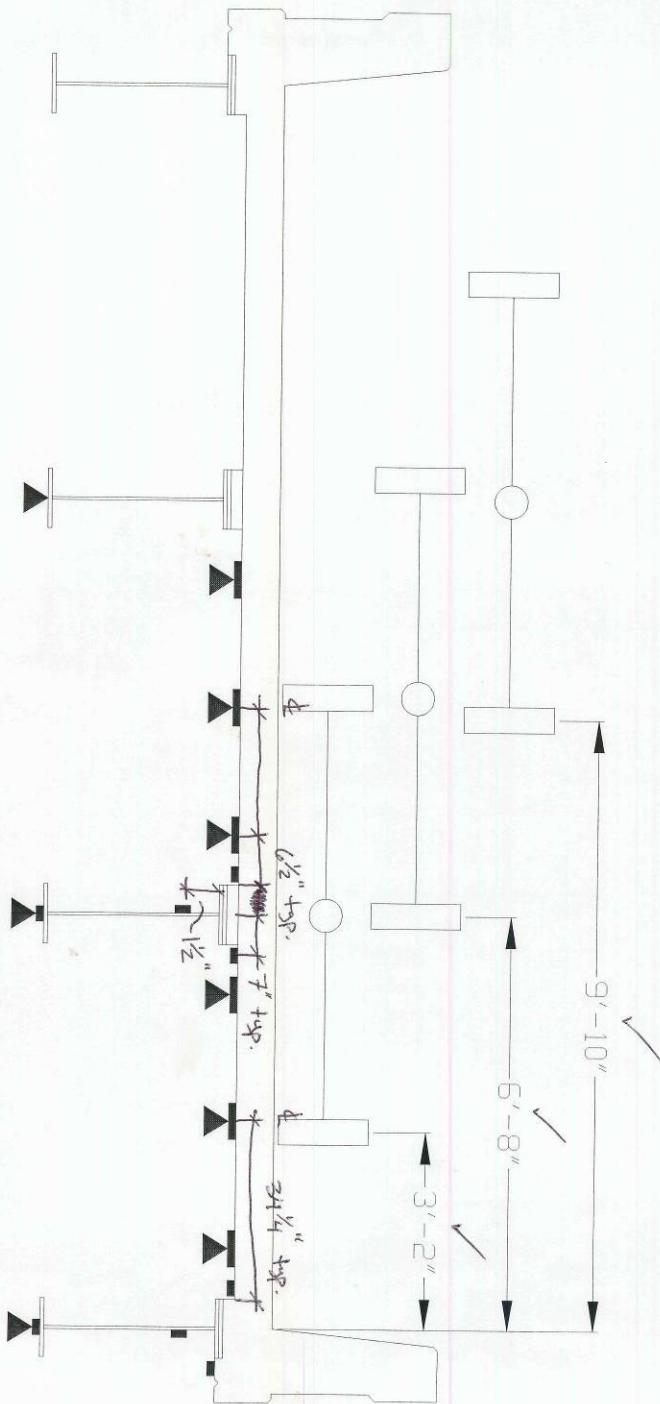
\*all Y3 passes 6" off (9'-110") due to big hole in the approach slab\*  
 $9\text{'-}4"$

Figure B.3 Scanned Notes- Page 3.



## Figure B.4 Scanned Notes- Page 4.

\*Note: All gages located in center of 31" long deck panels



**Figure B.5 Scanned Notes- Page 5.**

## C. APPENDIX C - FIELD TESTING PROCEDURES

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### **BACKGROUND**

The motivation for developing a relatively easy-to-implement field-testing system was to allow short and medium span bridges to be tested on a routine basis. Original development of the hardware was started in 1988 at the University of Colorado under a contract with the Pennsylvania Department of Transportation (PennDOT). Subsequent to that project, the Integrated Technique was refined on another study funded by the Federal Highway Administration (FHWA) in which 35 bridges located on the Interstate system throughout the country were tested and evaluated. Further refinement has been implemented over the years through testing and evaluating hundreds of bridges, lock gates, and other structures.

### **STRUCTURAL TESTING HARDWARE**

The real key to being able to complete the field-testing quickly is the use of strain transducers (rather than standard foil strain gages) that can be attached to the structural members in just a few minutes. These sensors were originally developed for monitoring dynamic strains on foundation piles during the driving process. They have been adapted for use in structural testing through special modifications, have very high accuracy, and are periodically re-calibrated to NIST standards. Please refer to Appendix D for specifications on the BDI Strain Transducers.

In addition to the strain sensors, the data acquisition hardware has been designed specifically for structural live load testing which means it is extremely easy to use in the field. Please see Appendix E for specifications on the BDI Structural Testing System. Briefly, some of the features include military-style connections for quick assembly and self-identifying sensors that dramatically reduce bookkeeping efforts. The WinSTS testing software has been written to allow easy hardware configuration and data recording operation. Other enhancements include the BDI AutoClicker which is an automatic load position indicator that is mounted directly on the vehicle. As the test truck crosses the structure along the preset path, a communication radio sends a signal to the STS that receives it and puts a mark in the data. This allows the field strains to be compared to analytical strains as a function of vehicle position, not only as a function of time. Refer to Appendix F for the AutoClicker specifications. The end result of using all of the above-described components is a system that can be used by people other than computer experts or electrical engineers. Typical testing times with the STS is usually anywhere from 20 to 60 channel tests being completed in one day, depending on access and other field conditions.

The following general directions outline how to run a typical diagnostic load test on a short-to medium-span highway bridge up to about 200 ft (60m) in length. With only minor modifications, these directions can be applied to railroad bridges (use a locomotive rather than a truck for the load vehicle), lock gates (monitor the water level in the lock chamber), amusement park rides (track the position of the ride vehicle) and other structures in which the live load can be applied easily. The basic scenario is to first instrument the structure with the required number of sensors, run a series of tests, and then removing all the sensors. These procedures can often be completed within one working day depending on field conditions such as access and traffic.

## ***INSTRUMENTATION OF STRUCTURE***

This outline is intended to describe the general procedures used for completing a successful field test on a highway bridge using the BDI-STS. For a detailed explanation of the instrumentation and testing procedures, please contact BDI and request a copy of the Structural Testing System (STS) Operation Manual.

## ***ATTACHING STRAIN TRANSDUCERS***

Once a tentative instrumentation plan has been developed for the structure in question, the strain transducers must be attached and the STS prepared for running the test. There are several methods for attaching the strain transducers to the structural members depending on whether they are steel, concrete, timber, FRP, or other. For steel structures, quite often the transducers can be clamped directly to the steel flanges of rolled sections or plate girders. If significant lateral bending is assumed to be present, then one transducer may be clamped to each edge of the flange. In general, the transducers can be clamped directly to painted surfaces. The alternative to clamping is the tab attachment method that involves cleaning the mounting area and then using a fast-setting cyanoacrylate adhesive to temporarily install the transducers. Small steel "tabs" are used with this technique and they are removed when testing is completed, and touch-up paint can be applied to the exposed steel surfaces.

Installation of transducers on pre-stressed concrete (PS/C) and FRP members is usually accomplished with the tab technique outlined above, while readily-available wood screws and a battery-operated hand drill are used for timber members. Installing transducers on reinforced concrete (R/C) is more complex in that gage extensions are used and must be mounted with concrete studs.

If the above steps are followed, it should be possible to mount each transducer in approximately five to ten minutes. The following figures illustrate transducers mounted on both steel and reinforced concrete members.



**Figure C.1 Strain Transducers Mounted on Steel Girder**



**Figure C.2 Transducers w/Gage Extensions Mounted On R/C Slab**

## ASSEMBLY OF SYSTEM

Once the transducers have been mounted, they are connected to the four-channel STS units which are also located on the bridge. The STS units can be easily clamped to the bridge girders, or if the structure is concrete and no flanges are available to set the STS units on, transducer tabs glued to the structure and plastic zip-ties or small wire can be used to mount them. Since the transducers will identify themselves to the system, there is no special order that they must be plugged into the system. The only information that must be recorded is the transducer serial number and its location on the structure. Signal cables are then used to connect STS units together either in series or in a “tree” structure through the use of cable splitters. If several gages are in close proximity to each other, then the STS units can be plugged directly to each other without the use of a cable.

Once all of the STS units have been connected together, only one cable must be run and connected to the STS Power Supply located near the PC. Once power and communication cables are connected, the system is ready to acquire data. One last step entails installing the AutoClicker on the test vehicle as seen in Figure C.3.



**Figure C.3 AutoClicker Mounted on Test Vehicle**

## ***ESTABLISHING LOADING VEHICLE POSITIONS***

Once the structure is instrumented and the loading vehicle prepared, some reference points must be established on the deck in order to determine where the vehicle will cross. This process is important so that future analysis comparisons can be made with the loading vehicle in the same locations as it was in the field. Therefore, a “zero” or initial reference point is selected and usually corresponds to the point on the deck directly above the abutment bearing and the centerline of one of the fascia beams. All other measurements on the deck will then be related to this zero reference point. For concrete T-beams, box beams, and slabs, this can correspond to where the edge of the slab or the beam web meets the face of the abutment. If the bridge is skewed, the first point encountered from the direction of travel is used. In any case, it should be a point that is easily located on the drawings for the structure.

Once the zero reference location is known, the lateral load paths for the vehicle are determined. Often, the painted roadway lines are used for the driver to follow if they are in convenient locations. For example, for a two-lane bridge, a northbound shoulder line will correspond to Y1 (passenger-side wheel), the center dashed line to Y2 (center of truck), and the southbound shoulder line to Y3 (driver’s side wheel). Often, the structure will be symmetrical with respect to its longitudinal center line. If so, it is good practice is to take advantage of this symmetry by selecting three Y locations that are also symmetric. This will allow for a data quality check since the response should be very similar, say, on the middle beam if the truck is on the left side of the bridge or the right side of the bridge. In general, it is best to have the truck travel in each lane (at least on the lane line) and also as close to each shoulder or sidewalk as possible. When the deck layout is completed, the loading vehicle’s axle weights and dimensions are recorded.

## ***RUNNING THE LOAD TESTS***

After the structure has been instrumented and the reference system laid out on the bridge deck, the actual testing procedures are completed. The WinSTS software is initialized and configured. When all personnel are ready to commence the test, traffic control is initiated and the Run Test option is selected which places the system in an activated state. When the truck passes over the first deck mark, the AutoClicker is tripped and data is being collected at the specified sample rate. An effort is made to get the truck across with no other traffic on the bridge. When the rear axle of the vehicle completely crosses over the structure, the data collection is stopped and several strain histories evaluated for data quality. Usually, at least two passes are made at each “Y” position to ensure data reproducibility, and then if conditions permit, high speed or dynamic tests are completed.

The use of a moving load as opposed to placing the truck at discrete locations has two major benefits. First, the testing can be completed much quicker, meaning there is less impact on traffic. Second, and more importantly, much more information can be obtained (both quantitative and qualitative). Discontinuities or unusual responses in the strain histories, which are often signs of distress, can be easily detected. Since the load position is monitored as well, it is easy to determine what loading conditions cause the observed effects. If readings are recorded only at discreet truck locations, the risk of losing information between the points is great. The advantages of continuous readings have been proven over and over again.

When the testing procedures are complete, the instrumentation is removed and any touch-up work completed.

## D. APPENDIX D – EQUIPMENT SPECIFICATIONS

---

### SPECIFICATIONS: BDI STRAIN TRANSDUCERS



Effective gage length:	3.0 in (76.2 mm). Extensions available for use on R/C structures.
Overall Size:	4.4 in x 1.2 in x 0.5 in (110 mm x 33 mm x 12 mm).
Cable Length:	10 ft (3 m) standard, any length available.
Material:	Aluminum
Circuit:	Full wheatstone bridge with four active 350Ω foil gages, 4-wire hookup.
Accuracy:	± 2%, individually calibrated to NIST standards.
Strain Range:	Approximately ±4000 $\mu\epsilon$ .
Force req'd for 1000 $\mu\epsilon$ :	Approximately 9 lbs. (40 N).
Sensitivity:	Approximately 500 $\mu\epsilon/mV/V$ ,
Weight:	Approximately 3 oz. (88 g),
Environmental:	Built-in protective cover, also water resistant.
Temperature Range:	-60°F to 250°F (-50°C to 120°C ) operation range.
Cable:	BDI RC-187: 22 gage, two individually-shielded pairs w/drain.
Options:	Fully waterproofed, Heavy-duty cable, Special quick-lock connector.
Attachment Methods:	C-clamps or threaded mounting tabs & quick-setting adhesive.

**SPECIFICATIONS: BDI WIRELESS STRUCTURAL TESTING SYSTEM**



Channels	4 to 128 (Expandable in multiples of 4)
Hardware Accuracy	$\pm 0.2\%$ (2% for Strain Transducers)
Sample Rates	0.1 – 500 Hz (Internal over-sampling rate is 19.5-312 kHz)
Max Test Lengths	21 minutes at 100 Hz. 128K samples per channel maximum test lengths
Gain Levels	1, 2, 4, 6, 16, 32, 64, 128
Digital Filter	Fixed by selected sample rate
Analog Filter	200 Hz, -3db, 3 <sup>rd</sup> order Bessel
Max. Input Voltage	10.5 Volts DC
Battery Power	9.6 NiMH rechargeable battery (Programmable low-power sleep mode)
Alternative Power	9-48 Volts DC input
<i>Excitation Voltages</i>	
Standard:	5 Volts DC
LVDT/Other:	5.5 Volts DC
A/D Resolution	0.3uV bit (24-bit ADC)
PC Requirements	Windows XP or higher
PC Interface	Wi-Fi Ethernet 802.11b: 10/100 Mbps
Auto Zeroing	Sensors automatically zero before each test
Enclosures	Aluminum splash resistant
Sensor Connections	All aluminum military grade, circular bayonet “snap” lock
Vehicle Tracking	BDI AutoClicker, switch closure detection
Sensors	BDI Intelliducer Strain Transducer Also supports, LVDT's, foil strain gages, accelerometers, Load Cell's and other various DC output sensors Single RS232 serially-interfaced sensor
<u>On-Board PC</u>	
Processor:	520 MHz Intel XScale PXA270
RAM:	64MB
Dimensions	
Base Station:	10" x 6" x 4"
STS 4-Channel Node:	11" x 3.5" x 3.23"

## **SPECIFICATIONS: BDI AUTOCLICKER**



3 Handheld Radios	Motorola P1225 2-Channel (or equal) modified for both “Rx” and “Tx”.
Power	9V battery
Mounting	Universal front fender mounting system
Target	Retroreflective tape mounted on universal wheel clamp
Bands/Power	VHF/1 Watt or UHF/2 Watt
Frequencies	User-specified
Data Acquisition System Requirements	TTL/CMOS input (pull-up resistor to 5V)
Output	Isolated contact closure (200V 0.5A max switch current)

## **E. APPENDIX G - REFERENCED MATERIAL**

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AASHTO (2003). "AASHTO LRFD Bridge Design Specifications." Washington,D.C.

AASHTO, (2003). "Manual for the Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges", Washington,D.C.

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Goble,G., Schulz,J., and Commander,B. (1992). "Load Prediction and Structural Response." Final Report, FHWA DTFH61-88-C-00053, University of Colorado, Boulder, CO.

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Schulz,J.L. (1993). "In Search of Better Load Ratings." *Civil Engineering*, ASCE 63(9),62-65.

Earney, T. Patrick. "Girder-End Cracking in Prestressed I-Girders". University of Missouri, Columia, MO.

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**REPORT OF CONCRETE AND MORTAR COMPRESSIVE STRENGTH USING CYLINDRICAL SPECIMENS – ASTM C39**

PROJECT NAME: Morris Road Bridge

CONCRETE REPORT NO.: C-01 SAMPLE NO: 9958

PROJECT NUMBER: HV10003

SAMPLE DATE: 1/14/10 DATE RCVD: 1/29/10

LOCATION: Redstone Arsenal, AL

WEATHER: Unknown

CLIENT: Angelo Iafrate Construction

CLIENT'S REP: Joe Eckardt

CONTRACTOR: Mandaree Enterprise Corporation

SUPERINTENDENT: N/A

CONCRETE SUPPLIER: Mixed on site

FIELD DATA REPORTED TO: N/A

**DESIGN & SPECIFICATION DATA**

MIX ID	SPECIFIED STRENGTH (psi)	SPECIFIED SLUMP (in)	SPECIFIED AIR CONTENT (%)	TEMPERATURE (°F)
N/A	1,000	N/A	N/A	N/A

MIX TYPE:  NORMAL WEIGHT  LIGHT WEIGHT  HEAVY WEIGHT  MORTAR  GROUT

**FIELD & PLACEMENT DATA**

BATCH TIME:	SAMPLE TIME:	TRUCK NUMBER:	TICKET NUMBER:	SIZE OF LOAD (cy):	SAMPLED BY:
Unknown	Unknown	N/A	N/A	Unknown	Contractor
METHOD OF PLACEMENT:	EXTRA WATER ADDED AT JOB SITE:	If Yes, gallons to cy	Extra Water Authorized By:		
<input checked="" type="checkbox"/> CHUTE <input type="checkbox"/> PUMP <input type="checkbox"/> OTHER	<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO <input type="checkbox"/> UNKNOWN				
SLUMP (in): (report to the nearest 1/4-inch)	AIR CONTENT (%): (report to the nearest 0.1%)	CONCRETE TEMP (°F): (report to the nearest 1°F)	AIR TEMP (°F): (report to the nearest 1°F)	UNIT WEIGHT (pcf): (report to the nearest 1 pcf)	
N/A ASTM C 143	N/A ASTM C 231	N/A ASTM C 1064	N/A	N/A ASTM C 138	

Location of Concrete or Mortar Placement: (should describe the total placement area, e.g. between Column Lines A,F,1, and 5 or Column Line A from 1 to 5)

Non-shrink grout used to camber bridge deck

Location of Concrete or Mortar Sample: (should describe the the exact location of the sampled material, e.g. Line A at 5)	Truck Sampled In Accordance With ASTM C172 At: Sampled at <u>  </u> yds <sup>3</sup> of <u>  </u> Truck total yds <sup>3</sup> Sampled at <u>  </u> yds <sup>3</sup> of <u>  </u> Total placement yds <sup>3</sup>
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Molded in accordance with ASTM C31:  YES  NO  UNKNOWN If no describe:

**REMARKS:**

Cylinders cast by contractor and field cured for 14 days. Contractor stated that compressive strength of non-shrink grout had to achieve 1,000 psi.

**COMPRESSIVE STRENGTH DATA**

SPECIMEN ID	DATE SAMPLED	DATE TESTED	AGE (days)	TEST SPECIMEN SIZE		TOTAL LOAD (pounds)	TEST STRENGTH (psi)	TYPE OF FRACTURE	TESTED BY	TESTING	LAB
				DIAMETER (in)	AREA (in <sup>2</sup> )						
9958 A	01/14/10	01/28/10	14	6.01	28.37	147,760	5,210	1	HB	HSV	
9958 B	01/14/10	02/11/10	28	6.02	28.46	168,060	5,910	1	DP	HSV	
9958 C	01/14/10	02/11/10	28	6.02	28.46	181,480	6,380	1	DP	HSV	

The average 28-day compressive strength ( 6145 p.s.i.) is 615% of the design compressive strength.

			TYPE OF FRACTURE	
Date of 1 <sup>st</sup> issue:	2/11/10	Results Reviewed by: Heath Black, PE	1: Cone both ends	
Date of 2 <sup>nd</sup> issue:	2/22/10	Results Reviewed by: Heath Black, PE	2: Cone one end w/ vertical cracks	
Date of 3 <sup>rd</sup> issue:		Results Reviewed by: _____	3: Columnar vertical cracking	
Final issue:		Results Reviewed by: _____	4: Diagonal fracture, no cracking	
			5: Side fractures, top or bottom	
			6: Side fractures, end pointed	

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**REPORT OF CONCRETE AND MORTAR COMPRESSIVE STRENGTH USING CYLINDRICAL SPECIMENS – ASTM C39**

PROJECT NAME: Morris Road Bridge

CONCRETE REPORT NO.: C-02 SAMPLE NO: 9959

PROJECT NUMBER: HV10003

SAMPLE DATE: 1/15/10 DATE RCVD: 1/29/10

LOCATION: Redstone Arsenal, AL

WEATHER: Unknown

CLIENT: Angelo Iafrate Construction

CLIENT'S REP: Joe Eckardt

CONTRACTOR: Mandaree Enterprise Corporation

SUPERINTENDENT: N/A

CONCRETE SUPPLIER: Mixed on site

FIELD DATA REPORTED TO: N/A

**DESIGN & SPECIFICATION DATA**

MIX ID	SPECIFIED STRENGTH (psi)	SPECIFIED SLUMP (in)	SPECIFIED AIR CONTENT (%)	TEMPERATURE (°F)
N/A	1,000	N/A	N/A	N/A

 MIX TYPE:  NORMAL WEIGHT  LIGHT WEIGHT  HEAVY WEIGHT  MORTAR  GROUT

**FIELD & PLACEMENT DATA**

BATCH TIME:	SAMPLE TIME:	TRUCK NUMBER:	TICKET NUMBER:	SIZE OF LOAD (cy):	SAMPLED BY:
Unknown	Unknown	N/A	N/A	Unknown	Contractor
METHOD OF PLACEMENT:	EXTRA WATER ADDED AT JOB SITE:	If Yes, gallons to cy	Extra Water Authorized By:		
<input checked="" type="checkbox"/> CHUTE <input type="checkbox"/> PUMP <input type="checkbox"/> OTHER	<input type="checkbox"/> YES <input type="checkbox"/> NO <input checked="" type="checkbox"/> UNKNOWN				
SLUMP (in): (report to the nearest 1/4-inch)	AIR CONTENT (%): (report to the nearest 0.1%)	CONCRETE TEMP (°F): (report to the nearest 1°F)	AIR TEMP (°F): (report to the nearest 1°F)	UNIT WEIGHT (pcf): (report to the nearest 1 pcf)	
N/A ASTM C 143	N/A ASTM C 231	N/A ASTM C 1064	N/A	N/A ASTM C 138	

Location of Concrete or Mortar Placement: (should describe the total placement area, e.g. between Column Lines A,F,1, and 5 or Column Line A from 1 to 5)

Non-shrink grout used to camber bridge deck

Location of Concrete or Mortar Sample: (should describe the the exact location of the sampled material, e.g. Line A at 5)	Truck Sampled In Accordance With ASTM C172 At: Sampled at <u>  </u> yds <sup>3</sup> of <u>  </u> Truck total yds <sup>3</sup> Sampled at <u>  </u> yds <sup>3</sup> of <u>  </u> Total placement yds <sup>3</sup>
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 Molded in accordance with ASTM C31:  YES  NO  UNKNOWN If no describe:

**REMARKS:**

Cylinders cast by contractor and field cured for 14 days. Contractor stated that compressive strength of non-shrink grout had to achieve 1,000 psi.

**COMPRESSIVE STRENGTH DATA**

SPECIMEN ID	DATE SAMPLED	DATE TESTED	AGE (days)	TEST SPECIMEN SIZE		TOTAL LOAD (pounds)	TEST STRENGTH (psi)	TYPE OF FRACTURE	TESTED BY	TESTING	LAB
				DIAMETER (in)	AREA (in <sup>2</sup> )						
9959 A	01/15/10	01/29/10	14	6.01	28.37	135,350	4,770	1	HB	HSV	
9959 B	01/15/10	02/12/10	28	6.02	28.46	176,250	6,190	1	DP	HSV	
9959 C	01/15/10	02/12/10	28	6.02	28.46	200,170	7,030	1	DP	HSV	

The average 28-day compressive strength ( 6610 p.s.i.) is 661% of the design compressive strength.

			TYPE OF FRACTURE	
Date of 1 <sup>st</sup> issue:	2/11/10	Results Reviewed by: Heath Black, PE	1: Cone both ends	
Date of 2 <sup>nd</sup> issue:	2/22/10	Results Reviewed by: Heath Black, PE	2: Cone one end w/ vertical cracks	
Date of 3 <sup>rd</sup> issue:		Results Reviewed by: _____	3: Columnar vertical cracking	
Final issue:	_____	Results Reviewed by: _____	4: Diagonal fracture, no cracking	
			5: Side fractures, top or bottom	
			6: Side fractures, end pointed	

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**REPORT OF CONCRETE AND MORTAR COMPRESSIVE STRENGTH USING CYLINDRICAL SPECIMENS – ASTM C39**

PROJECT NAME: Morris Road Bridge

CONCRETE REPORT NO.: C-03 SAMPLE NO: 9960

PROJECT NUMBER: HV10003

SAMPLE DATE: 1/29/10 DATE RCVD: 2/1/10

LOCATION: Redstone Arsenal, AL

WEATHER: Cloudy / Cold / Rain

CLIENT: Angelo Iafrate Construction

CLIENT'S REP: Joe Eckardt

CONTRACTOR: Angelo Iafrate Construction

SUPERINTENDENT: Kelly Crane

CONCRETE SUPPLIER: DCA / USA

FIELD DATA REPORTED TO: Kelly Crane

**DESIGN & SPECIFICATION DATA**

MIX ID	SPECIFIED STRENGTH (psi)	SPECIFIED SLUMP (in)	SPECIFIED AIR CONTENT (%)	TEMPERATURE (°F)
10C40H52	4,000	3 - 5	3 - 6	50 - 90

MIX TYPE:  NORMAL WEIGHT  LIGHT WEIGHT  HEAVY WEIGHT  MORTAR  GROUT

**FIELD & PLACEMENT DATA**

BATCH TIME:	SAMPLE TIME:	TRUCK NUMBER:	TICKET NUMBER:	SIZE OF LOAD (cy):	SAMPLED BY:
9:19	9:45	707	50524	8.25	DP
METHOD OF PLACEMENT:	EXTRA WATER ADDED AT JOB SITE:	If Yes, gallons to cy	Extra Water Authorized By:		
<input checked="" type="checkbox"/> CHUTE <input type="checkbox"/> PUMP <input type="checkbox"/> OTHER	<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO <input type="checkbox"/> UNKNOWN				
SLUMP (in): (report to the nearest 1/4-inch) 3 1/2 ASTM C 143	AIR CONTENT (%): (report to the nearest 0.1%) 3.8 ASTM C 231	CONCRETE TEMP (°F): (report to the nearest 1°F) 55 ASTM C 1064	AIR TEMP (°F): (report to the nearest 1°F) 34	UNIT WEIGHT (pcf): (report to the nearest 1 pcf) N/A ASTM C 138	

Location of Concrete or Mortar Placement: (should describe the total placement area, e.g. between Column Lines A,F,1, and 5 or Column Line A from 1 to 5)

Barrier rails for west side of bridge

Location of Concrete or Mortar Sample: (should describe the the exact location of the sampled material, e.g. Line A at 5)	Truck Sampled In Accordance With ASTM C172 At: Sampled at 1 yds <sup>3</sup> of 8.25 Truck total yds <sup>3</sup> Sampled at 1 yds <sup>3</sup> of 16.5 Total placement yds <sup>3</sup>
100 ft S of N end of barrier rails	

Molded in accordance with ASTM C31:  YES  NO  UNKNOWN If no describe:

REMARKS:

**COMPRESSIVE STRENGTH DATA**

SPECIMEN ID	DATE SAMPLED	DATE TESTED	AGE (days)	TEST SPECIMEN SIZE		TOTAL LOAD (pounds)	TEST STRENGTH (psi)	TYPE OF FRACTURE	TESTED BY	TESTING	LAB
				DIAMETER (in)	AREA (in <sup>2</sup> )						
9960 A	01/29/10	02/01/10	3	4.01	12.63	36,730	2,910	1	DP		HSV
9960 B	01/29/10	02/05/10	7	4.00	12.57	66,640	5,300	1	DP		HSV
9960 C	01/29/10	02/26/10	28	4.00	12.57	80,220	6,380	1	DP		HSV
9960 D	01/29/10	02/26/10	28	4.00	12.57	80,000	6,360	1	DP		HSV
9960 E	01/29/10	02/26/10	28	4.00	12.57	81,430	6,480	1	DP		HSV
9960 F	01/29/10	HOLD	H								

The average 28-day compressive strength (6407 p.s.i.) is 160% of the design compressive strength.

			TYPE OF FRACTURE	
Date of 1 <sup>st</sup> issue:	2/8/10	Results Reviewed by: Heath Black, PE	1: Cone both ends	
Date of 2 <sup>nd</sup> issue:	2/26/10	Results Reviewed by: Heath Black, PE	2: Cone one end w/ vertical cracks	
Date of 3 <sup>rd</sup> issue:		Results Reviewed by: _____	3: Columnar vertical cracking	
Final issue:		Results Reviewed by: _____	4: Diagonal fracture, no cracking	
			5: Side fractures, top or bottom	
			6: Side fractures, end pointed	

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## REPORT OF CONCRETE AND MORTAR COMPRESSIVE STRENGTH USING CYLINDRICAL SPECIMENS – ASTM C39

PROJECT NAME: Morris Road Bridge

CONCRETE REPORT NO.: C-04 SAMPLE NO: 10038

PROJECT NUMBER: HV10003

SAMPLE DATE: 3/1/10 DATE RCVD: 3/2/10

LOCATION: Redstone Arsenal, AL

WEATHER: Cloudy / Cool

CLIENT: Angelo Iafrate Construction

CLIENT'S REP: Joe Eckardt

CONTRACTOR: Angelo Iafrate Construction

SUPERINTENDENT: Kelly Crane

CONCRETE SUPPLIER: DCA / USA

FIELD DATA REPORTED TO: Kelly Crane

## DESIGN & SPECIFICATION DATA

MIX ID	SPECIFIED STRENGTH (psi)	SPECIFIED SLUMP (in)	SPECIFIED AIR CONTENT (%)	TEMPERATURE (°F)
10C40H52	4,000	3 - 5	3 - 6	50 - 90

MIX TYPE:  NORMAL WEIGHT  LIGHT WEIGHT  HEAVY WEIGHT  MORTAR  GROUT

## FIELD & PLACEMENT DATA

BATCH TIME:	SAMPLE TIME:	TRUCK NUMBER:	TICKET NUMBER:	SIZE OF LOAD (cy):	SAMPLED BY:
10:31	11:00	714	51363	9	DP
METHOD OF PLACEMENT:	EXTRA WATER ADDED AT JOB SITE:	If Yes, gallons to cy	Extra Water Authorized By:		
<input checked="" type="checkbox"/> CHUTE <input type="checkbox"/> PUMP <input type="checkbox"/> OTHER	<input type="checkbox"/> YES <input checked="" type="checkbox"/> NO <input type="checkbox"/> UNKNOWN				

SLUMP (in): (report to the nearest 1/4-inch) 3 1/2 ASTM C 143

AIR CONTENT (%): (report to the nearest 0.1%) - ASTM C 231

CONCRETE TEMP (°F): (report to the nearest 1°F) 64 ASTM C 1064

AIR TEMP (°F): (report to the nearest 1°F) 44

UNIT WEIGHT (pcf): (report to the nearest 1 pcf) N/A

ASTM C 138

Location of Concrete or Mortar Placement: (should describe the total placement area, e.g. between Column Lines A,F,1, and 5 or Column Line A from 1 to 5)

Barrier rails for bridge

Location of Concrete or Mortar Sample: (should describe the the exact location of the sampled material, e.g. Line A at 5)	Truck Sampled In Accordance With ASTM C172 At: Sampled at <u>1</u> yds <sup>3</sup> of <u>2</u> Truck total yds <sup>3</sup> Sampled at <u>10</u> yds <sup>3</sup> of <u>27</u> Total placement yds <sup>3</sup>
70 to 120 feet south of NW Corner	

Molded in accordance with ASTM C31:  YES  NO  UNKNOWN If no describe:

REMARKS:

## COMPRESSIVE STRENGTH DATA

SPECIMEN ID	DATE SAMPLED	DATE TESTED	AGE (days)	TEST SPECIMEN SIZE		TOTAL LOAD (pounds)	TEST STRENGTH (psi)	TYPE OF FRACTURE	TESTED BY	TESTING	LAB
				DIAMETER (in)	AREA (in <sup>2</sup> )						
10038 A	03/01/10	03/04/10	3	4.00	12.57	45,660	3,630	1	DP	HSV	
10038 B	03/01/10	03/08/10	7	4.01	12.63	53,970	4,270	1	DP	HSV	
10038 C	03/01/10	03/29/10	28	4.01	12.63	65,040	5,150	1	DP	HSV	
10038 D	03/01/10	03/29/10	28	4.01	12.63	67,080	5,310	1	DP	HSV	
10038 E	03/01/10	03/29/10	28	4.01	12.63	68,220	5,400	1	DP	HSV	
10038 F	03/01/10	HOLD	H								

The average 28-day compressive strength ( 5287 p.s.i.) is 132% of the design compressive strength.

			TYPE OF FRACTURE	
Date of 1 <sup>st</sup> issue:	3/15/10	Results Reviewed by: Heath Black, PE	1: Cone both ends	
Date of 2 <sup>nd</sup> issue:	3/31/10	Results Reviewed by: Heath Black, PE	2: Cone one end w/ vertical cracks	
Date of 3 <sup>rd</sup> issue:		Results Reviewed by: _____	3: Columnar vertical cracking	
Final issue:		Results Reviewed by: _____	4: Diagonal fracture, no cracking	
			5: Side fractures, top or bottom	
			6: Side fractures, end pointed	

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**REPORT OF CONCRETE AND MORTAR COMPRESSIVE STRENGTH USING CYLINDRICAL SPECIMENS – ASTM C39**

PROJECT NAME: Morris Road Bridge  
PROJECT NUMBER: HV10003  
LOCATION: Redstone Arsenal, AL  
CLIENT: Angelo Iafrate Construction  
CONTRACTOR: Angelo Iafrate Construction  
CONCRETE SUPPLIER: DCA / USA

CONCRETE REPORT NO.: C-05 SAMPLE NO: 10049  
SAMPLE DATE: 3/4/10 DATE RCVD: 3/5/10  
WEATHER: Cloudy / Cool  
CLIENT'S REP: Joe Eckardt  
SUPERINTENDENT: Kelly Crane  
FIELD DATA REPORTED TO: Kelly Crane

**DESIGN & SPECIFICATION DATA**

MIX ID	SPECIFIED STRENGTH (psi)	SPECIFIED SLUMP (in)	SPECIFIED AIR CONTENT (%)	TEMPERATURE (°F)
10C40H52	4,000	3 - 5	3 - 6	50 - 90
MIX TYPE:	<input checked="" type="radio"/> NORMAL WEIGHT <input type="radio"/> LIGHT WEIGHT <input type="radio"/> HEAVY WEIGHT		<input type="radio"/> MORTAR <input checked="" type="radio"/> GROUT	

**FIELD & PLACEMENT DATA**

BATCH TIME:	SAMPLE TIME:	TRUCK NUMBER:	TICKET NUMBER:	SIZE OF LOAD (cy):	SAMPLED BY:
9:57	10:22	507	51428	7	DP
METHOD OF PLACEMENT:	EXTRA WATER ADDED AT JOB SITE:				Extra Water Authorized By: Contractor
<input checked="" type="radio"/> CHUTE <input type="radio"/> PUMP <input type="radio"/> OTHER	<input checked="" type="radio"/> YES <input type="radio"/> NO <input type="radio"/> UNKNOWN		If Yes, 8 gallons to 7 cy		
SLUMP (in): (report to the nearest 1/4-inch)	AIR CONTENT (%): (report to the nearest 0.1%)	CONCRETE TEMP (°F): (report to the nearest 1°F)	AIR TEMP (°F): (report to the nearest 1°F)	UNIT WEIGHT (pcf): (report to the nearest 1 pcf)	
3 ASTM C 143	- ASTM C 231	57 ASTM C 1064	40	N/A	ASTM C 138

Location of Concrete or Mortar Placement: (should describe the total placement area, e.g. between Column Lines A,F,1, and 5 or Column Line A from 1 to 5)

Barrier rails for bridge

Location of Concrete or Mortar Sample: (should describe the the exact location of the sampled material, e.g. Line A at 5)	Truck Sampled In Accordance With ASTM C172 At: Sampled at 1 yds <sup>3</sup> of 7 Truck total yds <sup>3</sup> Sampled at 1 yds <sup>3</sup> of 14 Total placement yds <sup>3</sup>
East side rail bottoms beginning at NE Corner and extending 70' south	

Molded in accordance with ASTM C31:  YES  NO  UNKNOWN If no describe:

REMARKS:

**COMPRESSIVE STRENGTH DATA**

SPECIMEN ID	DATE SAMPLED	DATE TESTED	AGE (days)	TEST SPECIMEN SIZE		TOTAL LOAD (pounds)	TEST STRENGTH (psi)	TYPE OF FRACTURE	TESTED BY	TESTING	LAB
				DIAMETER (in)	AREA (in <sup>2</sup> )						
10049 A	03/04/10	03/07/10	3	4.01	12.63	51,280	4,060	1	DP		HSV
10049 B	03/04/10	03/11/10	7	4.01	12.63	55,230	4,370	1	DP		HSV
10049 C	03/04/10	04/01/10	28								
10049 D	03/04/10	04/01/10	28								
10049 E	03/04/10	04/01/10	28								
10049 F	03/04/10	HOLD	H								

The 7-day compressive strength ( 4370 p.s.i.) is 109% of the design compressive strength.

Date of 1 <sup>st</sup> issue:	3/15/10	Results Reviewed by: Heath Black, PE	TYPE OF FRACTURE 1: Cone both ends 2: Cone one end w/ vertical cracks 3: Columnar vertical cracking 4: Diagonal fracture, no cracking 5: Side fractures, top or bottom 6: Side fractures, end pointed
Date of 2 <sup>nd</sup> issue:		Results Reviewed by:	
Date of 3 <sup>rd</sup> issue:		Results Reviewed by:	
Final issue:		Results Reviewed by:	

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**REPORT OF CONCRETE AND MORTAR COMPRESSIVE STRENGTH USING CYLINDRICAL SPECIMENS – ASTM C39**

PROJECT NAME: Morris Road Bridge

CONCRETE REPORT NO.: C-06 SAMPLE NO: 10057

PROJECT NUMBER: HV10003

SAMPLE DATE: 3/9/10 DATE RCVD: 3/10/10

LOCATION: Redstone Arsenal, AL

WEATHER: Cloudy / Cool

CLIENT: Angelo Iafrate Construction

CLIENT'S REP: Joe Eckardt

CONTRACTOR: Angelo Iafrate Construction

SUPERINTENDENT: Kelly Crane

CONCRETE SUPPLIER: DCA / USA

FIELD DATA REPORTED TO: Kelly Crane

**DESIGN & SPECIFICATION DATA**

MIX ID	SPECIFIED STRENGTH (psi)	SPECIFIED SLUMP (in)	SPECIFIED AIR CONTENT (%)	TEMPERATURE (°F)
10C40H52	4,000	3 - 5	3 - 6	50 - 90

MIX TYPE:  NORMAL WEIGHT  LIGHT WEIGHT  HEAVY WEIGHT  MORTAR  GROUT

**FIELD & PLACEMENT DATA**

BATCH TIME:	SAMPLE TIME:	TRUCK NUMBER:	TICKET NUMBER:	SIZE OF LOAD (cy):	SAMPLED BY:
7:32	7:55	293	51655	8.5	DP
METHOD OF PLACEMENT:	EXTRA WATER ADDED AT JOB SITE:	If Yes, 8 gallons to 8.5 cy	Extra Water Authorized By: Contractor		
<input checked="" type="checkbox"/> CHUTE <input type="checkbox"/> PUMP <input type="checkbox"/> OTHER	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/> UNKNOWN				
SLUMP (in): (report to the nearest 1/4-inch) 2 3/4 ASTM C 143	AIR CONTENT (%): (report to the nearest 0.1%) - ASTM C 231	CONCRETE TEMP (°F): (report to the nearest 1°F) 67 ASTM C 1064	AIR TEMP (°F): (report to the nearest 1°F) 55	UNIT WEIGHT (pcf): (report to the nearest 1 pcf) N/A ASTM C 138	

Location of Concrete or Mortar Placement: (should describe the total placement area, e.g. between Column Lines A,F,1, and 5 or Column Line A from 1 to 5)

Barrier rails for bridge

Location of Concrete or Mortar Sample: (should describe the the exact location of the sampled material, e.g. Line A at 5)	Truck Sampled In Accordance With ASTM C172 At: Sampled at 1 yds <sup>3</sup> of 8.5 Truck total yds <sup>3</sup> Sampled at 1 yds <sup>3</sup> of 17 Total placement yds <sup>3</sup>
East side rail 70' south of north end	

Molded in accordance with ASTM C31:  YES  NO  UNKNOWN If no describe:

REMARKS:

**COMPRESSIVE STRENGTH DATA**

SPECIMEN ID	DATE SAMPLED	DATE TESTED	AGE (days)	TEST SPECIMEN SIZE		TOTAL LOAD (pounds)	TEST STRENGTH (psi)	TYPE OF FRACTURE	TESTED BY	TESTING	LAB
				DIAMETER (in)	AREA (in <sup>2</sup> )						
10057 A	03/09/10	03/12/10	3	4.02	12.69	47,590	3,750	1	DP	HSV	
10057 B	03/09/10	03/16/10	7	4.02	12.69	56,980	4,490	1	DP	HSV	
10057 C	03/09/10	04/06/10	28								
10057 D	03/09/10	04/06/10	28								
10057 E	03/09/10	04/06/10	28								
10057 F	03/09/10	HOLD	H								

The 7-day compressive strength ( 4490 p.s.i.) is 112% of the design compressive strength.

			TYPE OF FRACTURE		
Date of 1 <sup>st</sup> issue:	3/15/10	Results Reviewed by: Heath Black, PE	1: Cone both ends		
Date of 2 <sup>nd</sup> issue:	3/18/10	Results Reviewed by: Heath Black, PE	2: Cone one end w/ vertical cracks		
Date of 3 <sup>rd</sup> issue:		Results Reviewed by: _____	3: Columnar vertical cracking		
Final issue:	_____	Results Reviewed by: _____	4: Diagonal fracture, no cracking		
			5: Side fractures, top or bottom		
			6: Side fractures, end pointed		

# REPORT DOCUMENTATION PAGE

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1. REPORT DATE (DD-MM-YYYY)			2. REPORT TYPE		3. DATES COVERED (From - To)	
August 2016			Final			
4. TITLE AND SUBTITLE			Field Testing and Summary Report for Road 5 (Morris Road) Over Road 3 (Toftoy Throughway) at Redstone Arsenal, AL: Contractor's Supplemental Report for Project F09-AR16		5a. CONTRACT NUMBER W9132T-06-D-0001 (PO BDI0001)	
					5b. GRANT NUMBER	
					5c. PROGRAM ELEMENT Corrosion Prevention and Control	
6. AUTHOR(S)			Brett Commander and Scott Aschermann		5d. PROJECT NUMBER F09-AR16	
					5e. TASK NUMBER	
					5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)			Bridge Diagnostics, Inc. (BDI) 1965 57th Court North Suite 106 Boulder CO 80301		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			U.S. Army Engineer Research and Development Center Construction Engineering Research Laboratory PO Box 9005 Champaign, IL 61826-9005		10. SPONSOR/MONITOR'S ACRONYM(S) ERDC-CERL	
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13. SUPPLEMENTARY NOTES						
14. ABSTRACT  Cyclic loading and weathering of reinforced concrete bridge decks causes corrosion of reinforcement steel, which leads to cracking, potholes, and other problems. Under the Department of Defense Corrosion Prevention and Control Program (Project F09-AR16), a deteriorated concrete bridge at Redstone Arsenal, Alabama, was selected to demonstrate and validate a glass-fiber reinforced polymer (GFRP) composite deck system, which does not use any reinforcement steel. The results of that project were published as ERDC/CERL TR-16-6 (August 2016). Upon completion of the new GFRP composite deck system, Bridge Diagnostics, Inc. (BDI) was contracted to perform load testing to confirm that the bridge meets the structure's original 36-ton (HS-20) load rating and performance criteria for deflection and strain. This report documents the load test methods used by BDI and the results. The test results indicate that the demonstrated GFRP composite deck system met the strength design specifications and passed the deflection criteria.						
15. SUBJECT TERMS Glass fibers; Concrete—Service life; Concrete bridges—Floors; Polymeric composites; Fibrous composites; Concrete bridges—Maintenance and repair; Reinforced concrete—Corrosion; Materials--Dynamic testing						
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